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ORIGINAL ARTICLES

STATISTICAL STUDIES OF RECORDS OF INDIAN DAIRY CATTLE.

1. STANDARDISATION OF LACTATION PERIOD MILK RECORDS.

BY

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(Received for publication on 12th March 1931.)

(With 5 charts.)

Foreword.

The above article may be classed as the first serious study on modern lines of available statistics concerning Indian dairy cattle. The investigations which enabled the author to compile this article were made whilst he was a post-graduate student at the Imperial Institute of Animal Husbandry and Dairying and the greater part of his post-graduate study period at the Institute was taken up with this important research work. Mr. Lall Chand has carried out this work so thoroughly that it would be superfluous to attempt to describe what he has done in this foreword. His figures and deductions speak for themselves and indicate the spirit of patient investigation and careful research so necessary in this class of research. [Wm. Smith, *Imperial Dairy Expert.*]

Introduction.

The problems of Indian dairy cattle are highly complex and their solution bristles with difficulties. A statistical study of India shows that India has far too many cattle to successfully maintain them either for the work needs of the country or for her food supply, and that there is a considerable economic loss owing to the indiscriminate slaughter of cattle in cities. Besides, a comparison of the Indian with foreign cattle as regards their efficiency to supply either of the above mentioned needs reveals the fact that the majority of Indian cattle, judged by European standards, are quite inefficient, and are only fit to be destroyed. This deplorable state of affairs is mainly due to the actual cattle-breeding conditions existing in

India, for a very large number of cattle here have been bred from the maimed, the undersized, the unfit and the starved parents, and are bound to be unfit and useless animals according to the basic law of breeding—" Like begets like ".

Though the cattle of India measured by European standards are not economical or of first rate quality, they are without question the best tropical cattle in the world. Their power to withstand epizootic diseases and ability to stand a hot climate are factors of very great importance and value, and the best way of solving the Indian cattle problem is to improve them without sacrificing these qualities. To achieve this result it is necessary to establish and carefully maintain and breed herds of the best Indian breeds and eliminate from them by a process of selection and rejection all cattle below a certain fixed standard. This would gradually build up profitable herds of indigenous cattle and is the direction in which the large landowners can best serve their country.

The process of selection, however, is not as simple as it looks. Taking only one character, milk yield, for example, there are very great variations possible in it owing to the effect of environmental variations. For a proper selection it would be necessary that the effect of these environmental variations on milk yield be eliminated, or the milk yield records be first standardised to a definite common basis. Whereas a good deal of statistical work has been done in other countries in this line and results of practical application to cattle-breeders have been obtained therefrom, no attempt has to the author's best knowledge been made in this country so far to investigate how the milk yield of the best Indian breeds is affected by these environmental variations.

During the past 20 years a good deal of exact data regarding the milking capabilities of hundreds of Indian dairy cows has been obtained on Military and other Government farms. With a view to study the problem suggested above, a statistical analysis of the vast amount of data available about Indian cattle from these institutions offers to be a very fruitful line of research to a student interested in cattle-breeding.

Within the last few years Hammond and Sanders [1923] from Penrith Milk Recording Society data and Sanders from Norfolk Milk Recording Society data [1927, 1 ; 1927, 2 ; 1928, 1 ; 1928, 2], have conducted statistical studies of complete lactation milk records of English cows with the object of standardizing these for the four factors, season of year, service period, age, and dry period which mainly affect them. No attempt was made to study the effect of variations in management, it being assumed that this would be minimised for cows of the same herd. The eliminating corrections obtained by Sanders for Norfolk data [1928, 2] are given in Table I.

TABLE I.

Standardising corrections.

1. Month of calving
Standard—mean of all months

Month of calving	Correction %
January	—0·9
February	2·8
March	0·2
April	2·2
May	+3·4
June	7·0
July	5·0
August	3·0
September	0·5
October	—4·7
November	2·6
December	3·8

2. Age,
Standard—maturity 6th lactation

Age	Correction %
1st lactation	+30·6
2nd „	18·0
3rd „	9·3
4th „	3·7
5th „	0·7
6th „	..
7th „	+1·4
8th „	4·8
9th „	10·4
10th „	18·5
11th „	29·4
12th „	43·7

3. Length of service period
Standard—S. P.=85 days

S. P. in days	Corrections: 1st calvers	Corrections: Others
0—19	+28·2	+23·9
20—39	18·4	21·3
40—59	10·6	11·9
60—79	4·2	4·6
80—99	—1·1	—1·1
100—119	5·5	5·9
120—139	9·2	9·7
140—159	12·4	12·9
160—179	15·2	15·5
180—199	17·6	17·8
200—219	19·7	19·7
220—239	21·5	21·4
240—259	23·1	22·8
260—279	24·5	24·1
280—299	25·8	25·1
380—399	30·5	28·8
480—499	33·3	30·8

4. Length of dry period.
Standard—D. P.=40 days

D. P. in days	Corrections: 2nd calvers	Corrections: Others
0—9	+25·1	+14·0
10—19	15·2	8·8
20—29	8·0	4·7
30—39	2·8	1·5
40—49	—1·3	—1·2
50—59	4·4	3·3
60—69	6·4	5·0
70—79	8·8	6·5
80—89	10·4	7·6
90—99	11·7	8·6
100—110	12·7	9·4
110—119	13·5	10·1
120 and Over	14·8	11·7

A similar study of Indian milk records was, therefore, undertaken exactly on Sanders' lines, with the object of seeing how the elimination factors determined from them differed from those of Sanders, and how Indian cows compared with foreign cows in their milking capabilities. The results of this study for the first three factors are given in pages to follow.

MATERIAL AND METHODS.

On all the Government dairy farms in India, two classes of animals have been maintained, pure Indian and cross-breds. Of the pure Indian stock, the best and most well managed herds and which consequently give the most reliable data for such a study as this are the pure-bred Sahiwal herds at the Military Dairy Farms, Lahore and Ferozepur, and at the Imperial Institute of Agricultural Research, Pusa. Hence for the study of Indian cattle the milk records of the animals from these herds only have been utilized.

But by far the greatest number of animals bred and kept on these farms is of cross-breds. The milk records of the Military Dairy Farms' cross-breds, however, suffer from a very serious defect, for most of these animals go on moving from place to place along with troops, and consequently the milk-records produced by them are affected by another very potent factor hard to allow for, *i.e.*, change of locality and therefore climate, etc. None of these is therefore used in studying the effect of variation of these factors. The records of the Pusa cross-bred animals (1/2 Ayrshire-Sahiwal) which are free from this defect have been separately used in studying the effect of age on lactation milk yield in that breed.

Only normal lactation milk records were utilized, all lactations being considered abnormal and therefore excluded in which : –

(1) the cow failed to conceive again, and therefore in which S. P. could not be found ;

(2) the calf was allowed to suck the cow ;

(3) there was any serious illness ;

and

(4) the cow aborted.

1496 complete lactation milk records from pure bred Sahiwals and 348 from cross-breds were obtained and have been utilized for this study. Since Sanders' work has shown that the effect of the season of the year varies from district to district along with variations in herd management, only Lahore and Ferozepore records—1274 in number—were used for this factor. It is much regretted that due to the paucity and incompleteness of data in several respects the study of this factor could not be very exhaustive. Though the results obtained may not be quite conclusive, yet it may be said that a presumption has been laid that no such effect of the season of the year on milk yield seems to exist in our data as reported by Sanders. For the study of other factors all the 1496 records have been used. The terms season of the year, service period, age, and dry period have the same meaning as implied in Sanders' work.

Ordinary statistical methods as are necessary for the quantitative study of any variable like milk yield have been used. To gauge the significance of a difference probable error rather than the standard error has been used, a difference of less than four times the probable error being taken in general as having arisen from fluctuations of random sampling. This gives sufficiently high odds—142 : 1—against such a difference having arisen due to fluctuations of random sampling.

Discussion of Results.

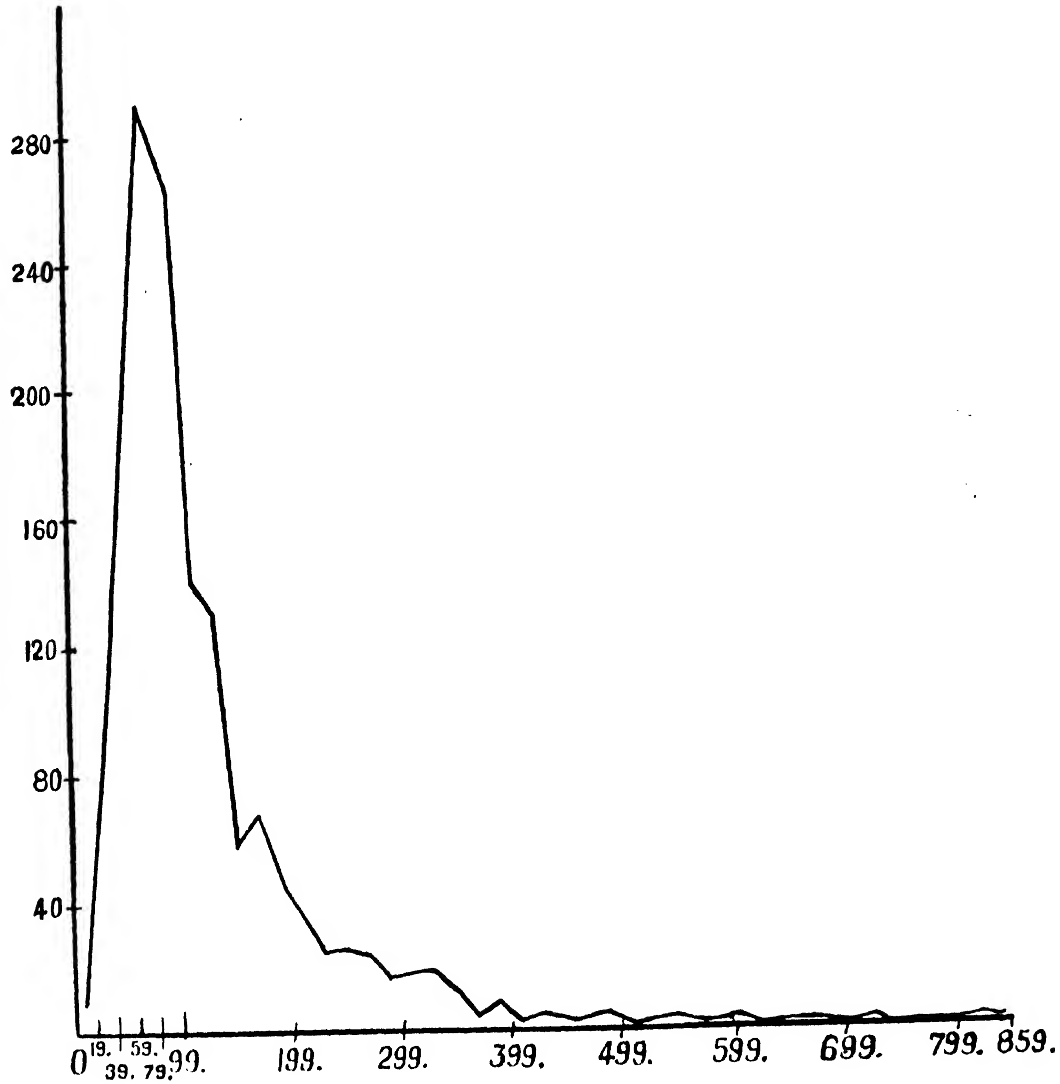
Preliminary considerations. Since the problem being studied is that of multiple correlation, it is but necessary to first study the distributions of different factors and the interrelations so that firstly the best method of attack of the problem may be selected and secondly due allowanca may be made for any relations that exist.

Distributions. The distribution of the 1271 Ferozepur lactations according to the month of calving is given in Table II.

Table II.

Month of calving	No. of cows calving	Per cent. of cows calving
January	133	10·44
February	175	13·74
March	204	16·01
April	145	11·38
May	129	10·13
June	63	4·94
July	67	5·26
August	56	4·39
September	42	3·30
October	67	5·26
November	79	6·20
December	114	8·95
Total	1,274	100·00

The figures are quite clear and require little comment. The percentage of calving for different months goes on increasing quite regularly from October, in which month only 5·26 per cent. of the total calved, to March, calving 16·01 per cent. of total. From this there is a steady decline till September—calving 3·30 per cent., the lowest for the year. This means that in these herds the largest number of cows calve in spring and smallest in autumn months.



Service period in days.

Fig. 1. Distribution of service period.

Figure 1 shows the frequency curve for the distribution of S. P. The mean S. P. for these 1496 lactations is 123·8 ∓ 1·7 days median 91·78 days and the mode lies at about 70 days. The standard deviation is 100·66 ∓ 1·2 days. Taking an average gestation period of 280 days it will mean that the average cow in these herds calves at an interval of 403·8 days or nearly every 13½ months, as against 1½ days less than a year for Sanders' [1927, 1] Norfolk data and 15½ days over a year for the Penrith data [1923].

Table III gives the distribution of these records according to age as measured in lactations.

TABLE III.

Lactation No.	Percentage of total included		
	Our data	Penrith	Norfolk
1	20·86	34·3	23·5
2	21 19	28·5	20·9
3	18·32	18·1	17·6
4	14·44	10·3	13·6
5	9·49	5·1	9·6
6	6·15	1·9	6·1
7	4·21	0·9	4·2
8	2·67	0·7	2·3
9	1·55	0·15	1·2
10	0·73	..	0·5
11	0·33	0·05	0·1
12	0·06	..	0·1
Older . . .	..	..	0·1
TOTALS .	100·00	100·00	100·00

It will be seen that in both our as well as Sanders' data the young cows are much more numerous than the older ones. This is because good many cows are kept in their early ages but are culled out later on due to poor production, only good milkers—comparatively fewer in number—being maintained till older ages. The average life of cows of our data is 3·37 lactations against Sanders 2·37 lactations for Penrith and 3·27 lactations for Norfolk data.

Of the 1496 milk records included in this study, the length of the preceding dry period is known only in the case of 1178 lactations, the distribution of which is given in the form of a frequency curve in Figure 2.

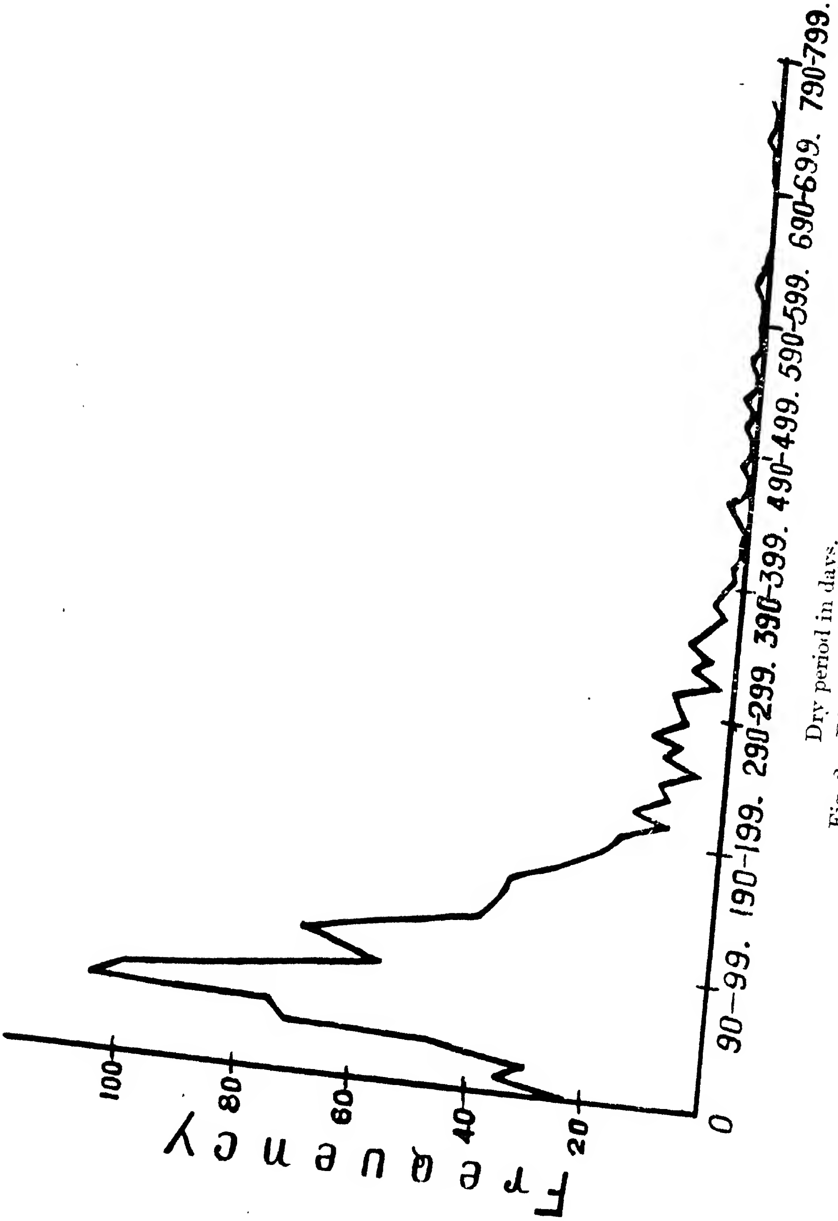


Fig. 2. Distribution of dry period.

The mean length of preceding D. P. for these 1178 lactations is $119 \cdot 74 \mp 1 \cdot 83$ days, the standard deviation being $93 \cdot 20 \mp 1 \cdot 30$ days. This mean is, however, much higher than Sanders' mean for mongrels (1167 observations) which is only $51 \cdot 3 \mp 0 \cdot 69$), showing thereby the uneconomic nature of our Indian cows due to comparatively a greater part of their lives being useless.

Interrelations. The variation of S. P. and D. P. with the season of year, *i.e.*, month in which a cow calves is shown in Table IV.

TABLE IV.

Showing variation of S. P. and D. P. with month of calving.

Month of calving	Mean S. P.	Mean D. P.
January	$104 \cdot 84 \mp 4 \cdot 69$	$117 \cdot 76 \mp 6 \cdot 87$
February	$114 \cdot 42 \mp 5 \cdot 02$	$112 \cdot 52 \mp 5 \cdot 42$
March	$103 \cdot 72 \mp 3 \cdot 63$	$110 \cdot 65 \mp 3 \cdot 50$
April	$111 \cdot 98 \mp 5 \cdot 98$	$113 \cdot 88 \mp 5 \cdot 20$
May	$125 \cdot 0 \mp 6 \cdot 41$	$107 \cdot 97 \mp 5 \cdot 19$
June	$136 \cdot 48 \mp 8 \cdot 80$	$126 \cdot 50 \mp 9 \cdot 30$
July	$139 \cdot 64 \mp 11 \cdot 93$	$135 \cdot 11 \mp 11 \cdot 05$
August	$130 \cdot 22 \mp 8 \cdot 94$	$122 \cdot 90 \mp 9 \cdot 97$
September	$139 \cdot 02 \mp 14 \cdot 45$	$121 \cdot 34 \mp 10 \cdot 62$
October	$121 \cdot 44 \mp 6 \cdot 85$	$125 \cdot 36 \mp 10 \cdot 43$
November	$146 \cdot 20 \mp 10 \cdot 17$	$113 \cdot 89 \mp 6 \cdot 60$
December	$121 \cdot 96 \mp 7 \cdot 20$	$105 \cdot 56 \mp 6 \cdot 14$
Mean of 12 months	124·58	116·98

The variation of both S. P. and D. P. with the month of calving though slight is quite significant. The S. P. is high for the months May to September mean being $132 \cdot 24 \mp 4 \cdot 21$ days, low for the months—January to April—$108 \cdot 62 \mp 2 \cdot 39$ days, and about average for the other 3 months. The difference of $23 \cdot 62 \mp 4 \cdot 84$ days between the mean S. Ps. of months with low S. P. and high S. P. is quite significant, it being 4·88 times its P. E. These results about the seasonal variation of S. P. are quite in accord with those of Sanders who too found the S. P. to be sub-normal for cows calving between February and June, and above the normal for the remaining months, although this variation is much more pronounced in our data than in his. The seasonal variation of S. P. has been interpreted by him as physiological in the light of researches of Hammond [1927] regarding the effect of the season of the year on the intensity and duration of oestrum.

The D. P. is above the normal for the months June to October—126·81 ∓ 4·68 and below the normal for the remaining months—mean 111·59 ∓ 2·02. The difference of 15·22 ∓ 5·09 between these two means, however, is not significant as it is only 2·99 times P. E. But since the figures for the variation of D. P. with calving months are very smooth running, more reliance might be placed on the differences between these monthly means than is indicated by their probable errors. It will be noticed that this seasonal variation of D. P. coincides with that of S. P. and since cows with long S. P. tend to have longer D. P. before they calve again than those with short S. P., the longer D. P. for the cows calving in June to October may partly be due to their longer S. P. This seasonal variation of D. P. is different to that in Sanders' data in which the mean D. Ps. are lower than the normal for the months July to October.

Table V shows the distribution of the milk records included in different calving months according to the ages at which these records were made.

TABLE V.

Relation of month of calving and age % in lactations.

% Distribution in different ages of total.

Calving month	1st lactation	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	Total.
January .	33·08	22·56	10·52	14·29	8·27	6·01	1·50	2·26	1·50	..	..	..	99·99
February .	21·71	20·0	17·14	13·14	9·72	7·43	5·72	2·86	..	1·41	1·57	0·57	100·00
March .	14·70	19·12	23·53	12·75	10·29	5·88	4·41	3·92	4·41	0·49	0·49	..	99·99
April . .	21·38	22·76	17·93	12·41	12·41	4·14	4·83	3·45	..	0·69	..	..	100·00
May . .	23·25	22·48	11·63	15·50	10·08	8·52	3·88	1·55	2·23	..	0·78	..	100·00
June . .	28.57	14·29	22·22	7·93	7·93	7·93	1·59	1·77	1·59	3·18	..	..	100·00
July . .	17·91	19·40	19·40	14·92	5·97	10·45	5·98	1·49	1·99	1·49	..	..	100·00
August .	8·93	17·86	16·07	14·29	12·50	7 15	8·93	10·72	..	1·78	1·78	..	100·00
September .	11·90	21·43	14·29	28·57	4·76	9·52	1·38	..	1·38	1·38	1·38	..	99·99
October .	12·12	16·67	24·24	19·70	9·09	6·06	9·09	1·51	1·51	..	..	..	99·99
November .	13·92	18·99	22·78	21·52	8·86	6·33	3·80	2·53	...	1·26	..	..	99·99
December .	18·26	17·39	19·13	14·78	13·01	4·35	5·22	3·48	3·48	0·87	..	..	100·00
Average .	19·94	19·86	18·13	14·76	9·89	6 59	4·63	3·14	1·81	0·87	0 39	0·08	99·99

The percentage distribution of cows of different ages in different calving months is far from uniform ; *e.g.*, 1st calvers constitute 33·08 per cent. of the total of January calvers, whereas in the months of April and September they constitute only 21·38 and 11·99 per cent. respectively. This goes to show that there exists in our data a relation between the age of cow and the month of calving.

The correlation coefficients as derived from the correlation surfaces drawn separately for the variable age and S. P. and age and D. P. were —·067 ∓ ·017 and

$+$ ·0688 $\mp$ ·0196 respectively. Neither of these two correlation coefficients is quite significant according to our arbitrary standard of 4 times the P. E., for the 1st value is only 3·94 times and the 2nd 3·51 times its probable error. But a careful study of the mean S. Ps. and D. Ps. for different ages revealed that these relations though not quite significantly high are quite true. The mean S. Ps. decrease quite regularly in our data, the means being 135·08 $\mp$ 3·90 days for 312 lactations of the 1st calf heifers, 129·18 $\mp$ 4·11 days for 317 records of the 2nd. 121·18 $\mp$ 4·03 for the 274 records of the 3rd lactation, 117·94 $\mp$ 3·28 for the 450 records for the 4th, 5th, and 6th lactations, and 108·78 $\mp$ 5·38 for the 137 records for the 7th, 8th, 9th and 10th lactations. This regular decrease in S. P. is perhaps due to the effect of selection, only selected animals being maintained in older ages.

The D. P. means for different ages, however, tended to increase slightly with increase of age explaining thereby the reason for the positive value of r, *e.g.*, the mean D. P. preceding the 315 records of 2nd calvers was 107·2, for the 274 records of 3rd calvers was 117·93 and for the 215 records of the 4th lactation was 127·47, there being a similar increase with increase in age.

No relation seemed to exist in this data between the S. P. and D. P. preceding. The value of the correlation coefficient for these two variables was $+$ ·0763 $\mp$ ·0195 or 3·91 times the P. E., which is not quite significant according to our standard. Moreover since these two variables did not seem to increase or decrease in any regular way, this low and rather insignificant value of r has been interpreted as having arisen due to errors of simple sampling.

The foregoing discussion regarding the interrelations of the 4 factors, season of the year, S. P., age and D. P. being studied here, leads us therefore to the following conclusions:—

(1) There exist relations in our data between the month of calving and age, S. P. and D. P. ;

(2) The S. P. decreases slightly with advanced age ;

(3) The D. P. increases slightly with advanced age ;

and

(4) There is no relation apparent between the S. P. and D. P. preceding.

Procedure employed during the study.

As has been mentioned before, the problem being studied is that of multiple correlation, hence the partial correlation method would be ideal provided the regressions permit its use on the basis of linearity. But as shall be shown later, such a complete analysis of all the factors being studied at one time is not possible since the regressions are decidedly non-linear. Consequently the method employed

has been the same as employed by Sanders, *i.e.*, study a factor first, get its elimination factors, apply them to the data and then study the next factor.

Season of the year was studied first, the idea being to see the extent of milk yield variation as caused by it, in order to decide if the data from the two different herds—Pusa and Military Dairy Farms could be combined into one for the study of other factors without serious loss of accuracy. It was observed that no definite seasonal variation in milk yield existed in our data, the variation for different calving months being quite erratic. Hence after its study the data from the two sources was all put together and studied for other factors. Since S. P. has been found to be least affected by interrelations of factors, the only relation noticed being a slight decrease in its value with advanced age, which in the author's opinion is not very serious, it was studied first, and the correction factors worked out for it. These were then applied to the data which was next used for the study of the variations of milk yield with age.

Variation of lactation milk yield as affected by: A. Season of the year.

From a table drawn to show the variation of the total lactation milk yield with the month in which a cow calves for the 1274 Military Dairy Farms' records, the statistical constants given in Table VI were worked out.

Table VI.

Variation of milk yield with season of year.

Month of calving	Mean milk yield	Standard deviation	Co-efficient of variation
January . . .	3851 $\pm$ 75 lbs.	1281 $\pm$ 53 lbs.	33·28 $\pm$ 1·52 per cent.
February . . .	4223 $\pm$ 70 ,,	1384 $\pm$ 50 ,,	32·77 $\pm$ 1·30 ,,
March . . .	4124 $\pm$ 79 ,,	1677 $\pm$ 56 ,,	40·67 $\pm$ 1·56 ,,
April . . .	3808 $\pm$ 93 ,,	1669 $\pm$ 66 ,,	43·84 $\pm$ 2·04 ,,
May	4125 $\pm$ 98 ,,	1654 $\pm$ 69 ,,	40·11 $\pm$ 1·94 ,,
June . . .	4646 $\pm$ 143 ,,	1684 $\pm$ 101 ,,	36·24 $\pm$ 2·44 ,,
July	4264 $\pm$ 137 ,,	1659 $\pm$ 97 ,,	38·91 $\pm$ 2·58 ,,
August . . .	4017 $\pm$ 151 ,,	1679 $\pm$ 107 ,,	41·81 $\pm$ 3·09 ,,
September. . .	4211 $\pm$ 217 ,,	2089 $\pm$ 151 ,,	49·57 $\pm$ 4·45 ,,
October . . .	4301 $\pm$ 131 ,,	1593 $\pm$ 93 ,,	37·04 $\pm$ 2·43 ,,
November . . .	4781 $\pm$ 140 ,,	1928 $\pm$ 103 ,,	40·33 $\pm$ 2·49 ,,
December. . .	4087 $\pm$ 110 ,,	1745 $\pm$ 78 ,,	42·09 $\pm$ 2·23 ,,
Mean of 12 months .	4204	1587	39·77

The mean milk yield for the different calving months varies between 3,800 and 4,800 lbs. with an average of 4,204 lbs. for all the 12 months, and the standard deviation lies in the neighbourhood of 1600 though it is rather exceptionally high

for the months September and November, when it well nigh reaches 2,000 lbs. The co-efficients of variation which vary from 32 to 50 per cent. with an average of about 40 per cent. are rather high when compared with those for other biological data as given by Gowen [1924] where the highest reported is only 38·2 per cent. although the majority of them fluctuate between 3 and 25 per cent.

Table VII gives what might be called the effect of the season of the year on lactation milk yield in our data, as compared with the same as obtained by other workers, for it gives the differences of the means of different calving months from the mean milk yield of 12 months.

TABLE VII.

Effect of the Season of year on milk yield. Differences in mean milk yield from mean of 12 months.

Month of calving	For present data	Sanders' [1923] Penrith	Sanders' [1927] Norfolk (uncorrected)	Sanders' [1923] N. Somerset
January . . .	—353	+153	+196	+562
February . .	+ 19	—162	+333	+331
March . . .	— 80	—192	+ 68	+169
April . . .	—396	—326	+ 108	+13
May . . .	— 79	—369	236	+87
June . . .	+442	—1040	—496	—377
July . . .	+ 60	—642	—318	-259
August . . .	—187	—473	—363	503
September . .	+ 10	+544	—218	—280
October . . .	+ 97	+1331	+214	+215
November . .	+577	+744	+226	+88
December . .	—117	+450	+490	+387

A comparison of our figures with others at once shows that this variation in our data is quite erratic, *e.g.*, in between the months December to May with sub-normal yield, there is the month of February which has a mean slightly above the normal, and in the months July to November giving a higher mean than the mean of 12 months is August whose yield is sub-normal. Furthermore, it will be seen that our figures lack smoothness which is so very characteristic of the figures given for other workers, for the peaks reached in our data during the two seasons are quite sudden, whereas had these figures been really influenced by the influence of the season of the year the variation ought to have been quite continuous and gradual.

These conclusions about the abrupt variations of milk yields for different calving months are further supported by Table VIII, which gives the differences between the mean yields for different calving months together with the probable errors of these differences.

TABLE VIII.

Significance of the differences between the monthly means.

—	January	February	March	April	May	June	July	August	September	October	November	December
January	—	**—342∓69**	—273∓74	+43∓80	—274∓83	**—795∓109**	—413∓105	—166∓114	—363∓154	**—450∓102**	**—930∓102**	—236∓90
February	..	—	+99∓71	**+415∓78**	+98∓81	—423∓107	—41∓104	+206∓112	+9∓154	—78∓100	**—568∓106**	+136∓88
March	..	..	—	+316∓82	+1∓85	**—522∓110**	+140∓107	+107∓115	+90∓155	—177∓103	**—657∓108**	+37∓89
April	..	..	..	—	—317∓90	**—838∓115**	**—456∓112**	—209∓119	—406∓159	**—493∓109**	**—973∓113**	—279∓98
May	..	..	..	..	—	**—521∓117**	—139∓113	+108∓121	—89∓161	—176∓111	**—656∓115**	+38∓100
June	..	..	..	..	..	—	+382∓134	**+629∓140**	+432∓182	+347∓131	—135∓135	**+559∓121**
July	..	..	..	..	..	..	—	+247∓138	+50∓173	—37∓127	—517∓132	+177∓119
August	..	..	..	..	..	..	..	—	—197∓178	—284∓135	**—764∓139**	+70∓124
September	..	..	..	..	..	..	..	..	—	—87∓170	—567∓173	+127∓164
October	..	..	..	..	..	..	..	..	..	—	—480∓130	+214∓115
November	..	..	..	..	..	..	..	..	..	..	—	**+694∓129**
December	..	..	..	..	..	..	..	..	..	..	..	—

Since with the same means the same figures though with opposite sign would be obtained in the lower left half portion of Table VIII as are given in its upper right half, these are omitted. It will be seen that the only significant differences—differences at least four times their P. E's, and which are printed in bold type—are between the means of the 2 months June and November and those of the remaining months, all other differences except a few stray ones scattered here and there being quite insignificant.

Again a comparison of the mean milk yields for different calving months with their corresponding mean S. P. and D. P. shows that the mean total and both S. P. and D. P. of cows calving in each month show a marked resemblance, *e.g.*, both the D. P. and S. P. are below the average for the months December to May—months with lower mean yields—and above the normal for other months -months with higher mean yields; and since the effect of the season of the year is only very slight on milk yield as compared with the same for S. P. and D. P., in the author's opinion, majority of these seasonal variations of milk yield in this data would be cancelled when the due allowance is made for the seasonal variation of S. P. and D. P. The only variations that might still remain, though these too will be very much reduced, will be for the months June and November—months with exceptionally high yields for no apparent reason.

The consideration of all this has led the author to believe that there does not exist in this data any very great effect of the season of the year on the lactation milk yield, and that any differences that do exist between the means of different calving months and the average of 12 months, are perhaps merely due to the fact that the cows of different grades of production are not equally distributed in different calving months, *i.e.*, cows calving in months from June to November have a larger proportion of high producers amongst them than those calving in the months December to May—a claim to disprove which we have unfortunately no data at hand for it can best be seen by the study of the drop curves for different calving months, though there is some presumptive evidence in its favour.

The work of Sanders [1927,1] has proved conclusively that the seasonal variation in milk yield, which is the result of the variations of the monthly drop of milk yield - persistency factor of lactation curve- from month to month is "nutritional rather than meteorological" and is an inverse index of the herd management, *e.g.*, he has shown from Norfolk data the effect of young grass in spring in putting up the yield—spring flush due to the very succulent nature of grass and its high nutritive value—, which is followed by a decline as the grass

gets older and therefore deteriorates in its nutritive value; furthermore that this seasonal variation is much more pronounced in Penrith than in Norfolk because of the feeding of roots and other succulent foods to Norfolk cows as compared with Penrith ones during the hot months when pastures parch and dry off and therefore there is scarcity of succulent food and whatever grass there is, it is very fibrous and low in nutritive value.

A consideration of the above results as reported by Sanders together with a study of the actual conditions under which the animals of our data have made their records further supports the claim that these differences in milk yield means for different calving months cannot be very significant, for the system of herd management at these Military Dairy Farms is more or less perfect as an attempt is always made to keep the feeding and management conditions quite uniform throughout the year by stall feeding. Adequate protection from inclemencies of weather is always provided by way of proper housing. Supply of succulent fodder is ensured all the year round, either in the form of green fodder—there being no pastures—or silage when green fodder is not available, though in the winter months roots, etc., are also fed, and during the months roughages are of poor quality they are supplemented by a fixed though liberal concentrate allowance. Under such ideal conditions of herd management it is only too natural that there be no very great seasonal variation of milk yield. That such is very probably actually the case is shown by the results given above, hence no corrections have been applied for this factor to the data. In this connection it might as well be noted that it is by no means the intention of the author to imply that the lactation milk yield of a cow cannot be affected by her month of calving. That such an effect is possible is fully realized though its presence in the data reported is rather doubtful. This conclusion, however, requires further investigation.

Variation of lactation milk yield as affected by :- B. Service Period.

The distribution of the S. P. and its relations with the other three factors in our data have already been discussed. In the present section an attempt has been made to study the effect of S. P. on total lactation milk yield. To do this a correlation surface was drawn for these two variables, *i.e.*, milk yield and S. P. and the mean milk yields worked out for the different service-period intervals, a study of which showed the variation of milk yield with S. P. to be quite regular and definite, the means for successive S. Ps. being quite smooth running. The main statistical constants as derived from the same table are given in Table IX.

TABLE IX.

Correlation of milk yield with S. P.

Mean milk yield	4069 ∓ 28 lbs.
Standard deviation of milk yield	1612 ∓ 20 „
Mean S. P.	123·8 ∓ 1·7 days.
Standard deviation of S. P.	100·66 ∓ 1·2 „
Correlation coefficient	+·339 ∓ ·015
„ ratio milk yield on S. P.	·389 ∓ ·015
$n^2 - r^2$	·0364 ∓ ·0067
Equation of fitted curve	$Y = 5960 - 3033\, e^{-\cdot00417x}$

where Y = lactation yield lbs.
e = natural base of neparian logarithms.
x = S. P. in days.

The value of correlation coefficient is fairly high and is many times its probable error and consequently is quite significant, meaning thereby that milk yield and S. P. are causally correlated. The correlation ratio, as would be expected, is higher than correlation coefficient though the difference between the two ·050 ∓ ·014 is not quite significant, it being only 3·57 times its P. E.

The value of $n^2 - r^2$, the test for linearity of regression is ·0364 ∓ ·0067, which, though low as these values generally are, is quite significant, it being 5·43 times its P. E. This would mean that the relation between mean lactation milk yield and S. P. is not linear in nature, and in fact a study of the mean milk yields for different S. Ps. quite justified this conclusion, for the mean yields increased at a decreasing rate for successive S. P. intervals apparently tending to a limit. Moreover the fact that the relation between mean lactation yield and S. P. can be linear is quite belied by the modern researches about the form of lactation curve, for linearity would mean that a cow never served would milk indefinitely whereas Brody, Ragsdale and Turner [1923] have shown that " the form of the equation for the lactation curve is the form that also describes the course of a monomolecular reaction, that there is present some material of the nature of a catalyst which acts as a necessary intermediary in the chemical process involved, and that the catalyst is very slowly and continuously destroyed in accordance with the differential equation $\frac{dy}{dt} - a\, e^{-kt}$ "

Keeping in view all these different considerations, it was decided to fit a logarithmic curve of the form $y = A - Be^{-cx}$ to the mean milk yields for different S. Ps. Trial gave the curve,

$$y = 5960 - 3033\, e^{-\cdot00417x}$$

whose fit to the actual means for different S. Ps. is shown in Figure 3. It will be seen that the fit of theoretical curve to observational means is very good indeed.

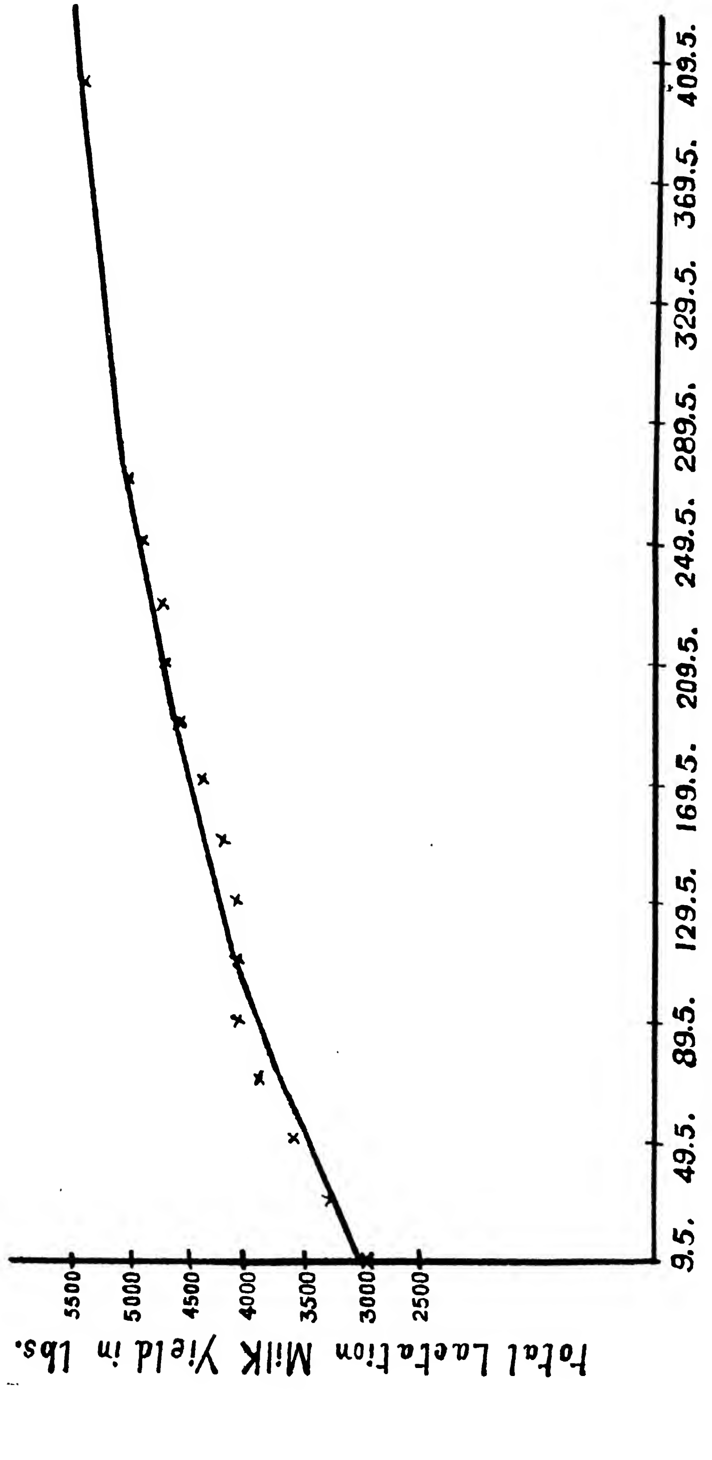


Fig. 3. Effect of the length of service period on total lactation milk yield.

According to this curve the lactation yield of an average cow would be 3,033 lbs. only if conception occurred at once after calving and 5,960 lbs. as a limit if breeding were indefinitely postponed. From this equation a set of correction factors as given in Table X, has been derived by using standard S. P. of 85 days, for making allowance for varying lengths of S. P.

TABLE X.

Corrections to total yield for S. P. (standard S. P.=85 days, mean yield for 85 days S. P.=3,832 lbs.).

Service period	Corresponding mean total yield from smooth curve	3832 / Value from 2 (correct factor)	Per cent. correction to apply	Per cent. correction from Penrith data (1)
	lbs.			
9·5	3,045	1·258	+ 25·8	+ 26·0
29·5	3,278	1·169	16·9	17·0
49·5	3,493	1·097	9·7	9·7
69·5	3,690	1·038	3·8	3·9
89·5	3,872	0·989	—1·1	—1·0
109·5	4,039	0·948	5·2	5·0
129·5	4,193	0·914	8·6	8·5
149·5	4,334	0·884	11·6	11·4
169·5	4,464	0·858	14·2	14·0
189·5	4,584	+ 0·835	16·5	16·2
209·5	4,694	0·816	18·4	18·1
249·5	4,888	0·784	21·6	21·2
289·5	5,051	0·758	24·2	23·7
329·5	5,192	0·738	26·2	25·6
369·5	5,310	0·721	27·9	27·2
409·5	5,410	0·709	29·1	28·5

85 days S. P. has been selected as the standard, as with this S. P. and a normal gestation period of 280 days the cow will calve at yearly intervals. Since a long S. P. increases the lactation milk yield and a short one depresses it, a percentage as given in Table X for corresponding S. P. must be added to lactation yield for all S. Ps. below 85 days, and a percentage subtracted from it for all periods higher than 85 days. For the sake of comparison, the elimination corrections for Penrith as obtained by Sanders [1923] and recalculated to a standard of 85 days S. P. are also included in Table X. It will be seen that the two sets of figures agree admirably well though our corrections are a trifle lower for the S. Ps. below 85 days and a trifle higher for the S. Ps. above 85 days.

The correction factors given for varying lengths of S. P. shew very clearly the very great potency of S. P. in influencing the total lactation yields for a reference to Table X will show that milk yielded by a cow in a lactation must be raised by 26 per cent. if she is served 9·5 days after calving, and lowered by 28·5 per cent. if she is left empty for 409·5 days after calving, in order to see what she would have produced with a S. P. of 85 days. It must, of course, be mentioned that these correction factors for different S. Ps. are strictly true for the mid-value of the intervals. But since the variation of milk yield with S. P. is a continuous one, more accurate results would be obtained if the corrections for the S. Ps. lying in the intervals, the means of which are only given in Table X, be interpolated by ordinary linear interpolation ; especially will this be necessary for very low S. Ps. when the mean lactation yields are rising very rapidly with successive S. Ps.

Causes of variation of milk yield with S. P.

It is generally realized that the length of lactation is determined to a very great extent by the length of its S. P. The problem has been the subject of study at different places all over the world with more or less similar results regarding the extent of correlation existing between these two variables. Ellinger [1910?], for instance, dealing with Red Danish breed got a very high value of correlation coefficient between these two variables $r = +\cdot943 \mp \cdot005$. Sanders [1927, 1], however, working on the same problem got the following results :-

	r	n	regression equation
1st calvers	$+\cdot795 \mp \cdot008$	$\cdot811 \mp \cdot008$	35·70 + 0·105 S. P.
Others	$+\cdot758 \mp \cdot008$	$\cdot760 \mp \cdot005$	33·30 + 0·109 ,,

As will be seen, the value of r is quite high though it is much lower than that of Ellinger, and close agreement between r and n justifies the use of a linear regression equation. Both these sets of correlation coefficients, however, seem to the author rather high and therefore over-estimating the true physiological relationship existing between these two variables. In fact, Sanders himself admits

this fact in his work, for according to him "there always are some very long S. Ps. being associated with only moderately long lactations and these are often excluded automatically from the data by the farmers selling the cow before she conceived."

There seemed little evidence, however, of this defect in our data, and it was, therefore, thought that the value of r obtained from it would approximate more nearly the true physiological relationship than the same of Sanders' or Ellinger's. A correlation surface was therefore drawn between these two variables, a close study of which revealed that whereas there appeared to be quite a high value of r between the two variables, *i.e.*, a high value of S. P. seemed to be generally associated with a long lactation, there were good many cases where the S. P. had been longer than the lactation length accompanying it, this being especially true for very long S. Ps. This led the author to the belief that the length of lactation, though generally governed by S. P., tended to a limit even though the length of the S. P. be infinitely increased, and therefore the true relation between the two variables is not linear in nature as given by Sanders, for on the basis of Sanders' linear equations a cow once in milk will milk infinitely provided she is kept away from the bull, and that the lactation length increases regularly at the rate of 10·5 weeks for every 100 days the date of service is deferred in first calvers. All these beliefs are quite substantiated by the statistical constants given in Table XI and as derived from the said correlation surface.

TABLE XI.

Correlation of S. P. with lactation length.

Mean S. P.	123·8 ± 1·78
Standard deviation S. P.	100·66 ± 1·25
Mean length of lactation	291·69 ± 1·23
Standard deviation length of lactation	70·64 ± 0·91
r	+ ·524 ± ·013
n	·590 ± ·001
$n^2 - r^2$	·0735 ± ·0095

As expected the value of r is considerably lower than that of Sanders or Ellinger, though it is still quite high and highly significant. The value of n is nearly quite significantly higher than that of r, n r being ·066 ± ·017 or 3·88 times its P. E., and the value of n^2 r^2 does not permit the use of linear equation to describe the function. All this means that though the relation between these two

variables is not quite linear, their degree of correlation is quite high, *i.e.*, a high S. P. will go with a long lactation period.

Again though no similar statistical constants for the relationship existing between the lactation length and total milk yielded in it are known to the author to have been determined as between S. P. and lactation length, yet it is common knowledge that the total amount of milk produced during any lactation, *i.e.*, from parturition to the end of lactation or until recurrence of parturition, is greatly influenced by the length of time over which the lactation extends. From the correlation surface drawn for these two variables for our data the statistical constants given in Table XII were obtained :—

TABLE XII.

Correlation of milk yield with lactation length.

Mean milk yield	4069 ∓ 28 lbs.
Standard deviation milk yield	1612 ∓ 20 „
Mean lactation length	291·69 ∓ 1·23 days
Standard deviation lactation length	70·64 ∓ 0·91 „
r	+·695 ∓ ·009
n	·723 ∓ ·008
$n^2 - r^2$	·0397 ∓ ·007

Although the value of r as given above does not represent the true physiological relationship between the two variables, for the length of lactation is generally a controlled factor in most herds, yet its very high positive value leaves no doubt in its significance. The value of $n^2 - r^2$ is again interesting; for it together with the value of r shows that though with longer lactation periods one gets more milk yet the rate of increase is not expressed by a linear equation but is represented in some other form.

The above discussion about the relations between the S. P., lactation length and milk yield therefore goes to explain the cause of the variation of lactation milk yield with S. P., for it clearly brings out that since S. P. and lactation length and lactation length and lactation milk yield are all positively correlated, a longer S. P. in a cow results in a longer lactation and therefore more milk yield as against shorter one in which the length of lactation and consequently the milk yield are both reduced.

Before this discussion about the causes of variation of milk yield with S. P. is left off, it must of course be mentioned that this is not the only way in which

S. P. affects the lactation yield, for modern researches [Sanders, 1927, 2] have gone on to show that S. P. also affects the shape of lactation curve, the curve being long flat in nature—more persistent—for cows whose S. P. is longer, as against the steep one of those that are served earlier and therefore have shorter S. Ps.

VARIATION OF LACTATION MILK YIELD AS AFFECTED BY :—C. AGE.

Of the different factors that are being considered here, age perhaps has received the most consideration at the hands of different workers in the world, though the methods employed in its study have differed considerably with different workers. But by far the commonest method employed has been the study of what Sanders calls "raw lumped lactations." This method, however, is highly unsatisfactory, and the results got by it do not represent the real physiological function of age in the variation of milk yield, for "conscious, unconscious and conscious and unconcious selection" [Kay and M'Candlish, 1929] is always going on in every herd in any of its 3 forms, and, therefore, the milk records included in the older ages as against those for younger ages are always from selected animals which are naturally better producers with the result that a higher age of maximum production is obtained than what it ought to have been if due allowance had been made for selection.

A decided improvement on this method of studying the variation of milk yield with age from "raw lumped lactations", therefore, is the elimination of the effect of selection from the data before it is utilized for this study. This may be achieved in any of the following two ways:—

1. Fixing a standard for age so that only those cows be included in the study which have completed that age standard, *e.g.*, it may be fixed that no cows be taken into consideration that have been in herd for less than 5 lactations. In that case the variation of milk yield for 5 lactations will represent the underlined physiological function truly. But the defect of the method is that a good lot of cows which do not reach the affixed standard are left out of consideration.

2. A more practical method is the one laid out by Sanders [1928, 1] for studying the variation of individual cow's milk yield with age, which seeks at building up a composite curve. In this case all the known records are utilized.

But although the results got after allowing for selection are better and more representing the true physiological function than those got from "raw lumped lactations", yet they are not final, for allowance must be made for the interrelations of other factors with age which also affect milk yield. The variation got when due allowance is made for them all after allowing for selection represents truly the underlying physiological function.

In the present study all the three methods as described above have been used, though the final corrections have been worked out by the last method only, *i.e.*, by eliminating selection and the effect of the variation of S. P. with age.

" *Raw lumped lactations* ". The mean yields for different ages as derived from the distribution surface drawn between age—as measured in lactations—and the lactation milk yield, are given in Table XIII, a study of which

TABLE XIII.

Age in lactations	Milk yield
	lbs.
1	3,763
2	4,033
3	4,098
4	4,216
5	4,065
6	4,124
7	4,331
8	4,105
9	3,755
10	4,647
11	4,774

shows that these means for different ages are rather irregular, and therefore it is not possible to fix the age of maximum production to which the yields of other ages be standardized. The highest mean yield is first attained at the 4th lactation over which there is a decrease during the next two lactations, *i.e.*, 5th and 6th. The 7th lactation mean is higher than all its preceding ones and then there is drop again during the 8th, and 9th lactations, the 10th and 11th lactations being again exceptionally high perhaps because only selected animals—animals retained on account of their producing ability—are included in these age classes.

Composite curve method. The fact that the mean yields for different ages as given in Table XIII do not represent the real variation of milk yield with age, is very clearly brought out by a study of the same by the composite curve method.

In this data there were 310 cows whose first two lactations were known and the mean yields for the first and 2nd lactations were 3,767 and 4,067 lbs. respectively, or putting the 1st lactation yield at 100·0 that for the 2nd came to 108·05. Similarly there were 263 cows with 2nd and 3rd lactation known giving means of 4,095 and 4,103 lbs. respectively; if the 2nd lactation yield is taken at 108·05, that for 3rd becomes 108·26 the comparative yields for the 1st, 2nd and 3rd lactations being 100·0, 108·05 and 108·26. The same process was continued for all other ages and the comparative yields got for different ages are given in Table XIV.

TABLE XIV.

Age in lactations	Comparative yield
1	100·00
2	108·05
3	108·26
4	108·91
5	104·23
6	102·67
7	100·00
8	89·50
9	83·68
10	82·34

A study of these comparative yields shows that these means increase till 4th lactation, though the extent of increase between the lactations 3rd and 4th is very small, and then decrease continuously. These means have not been smoothened in any way, for it is thought that even these do not represent the true relationship of the variation of milk yield with age, for in the first section of this paper it was shown that age is slightly related with both S. P. and D. P. It was not possible to allow for the 2nd, but the effect of the 1st was eliminated by standardizing all lactation yields first to 85 days S. P., and from the corrected lactation yields, a composite curve was built again just in the same way as described above.

The actual distribution of these corrected lactation yields according to age is given in Table XV, the means for the different ages being given at the foot of the same Table.

TABLE

Variation of lactation yield with age—

Lactation

Total lactation yields in lbs	1	2	2	3	3	4	4
Below 499	2	..	..	2	1	..	..
500—749	5	..	..	1	..	2	1
750—999	..	..	..	..	..	..	..
1000—1249	7	3	2	1	1	3	3
1250—1499	7	8	8	1	1	2	1
1500—1749	3	6	4	5	4	3	1
1750—1999	16	9	9	6	..	6	6
2000—2249	16	12	8	15	12	7	1
2250—2499	8	16	14	11	8	5	3
2500—2749	24	17	13	14	12	12	9
2750—2999	20	21	17	19	13	11	6
3000—3249	28	15	9	17	14	15	10
3250—3499	19	24	21	18	16	12	8
3500—3749	28	26	23	21	14	15	10
3750—3999	26	21	18	17	14	14	11
4000—4249	23	18	16	13	9	11	10
4250—4499	11	27	24	19	19	10	9
4500—4749	13	18	16	8	7	12	8
4750—4999	11	11	10	21	19	16	10
5000—5249	15	9	9	11	9	8	6
5250—5499	6	12	8	8	6	7	4
5500—5749	6	8	7	6	6	12	9
5750—5999	6	7	7	9	8	6	2
6000—6249	4	7	7	4	4	3	3
6250—6499	1	3	3	2	2	4	2
6450—6749	1	2	2	5	2	4	3
6750—6999	1	3	2	3	2	3	2
7000—7249	2	1	1	2	3	1	1
7250—7499	..	1	1	..	..	..	..
7500—7749	..	2	1	1	1	3	1
7750—7999	1	1	1	..	..	1	..
8000—8249	..	..	..	2	2	..	..
8250—8499	..	1	1	..	..	1	1
8500—8749	..	..	..	..	..	..	..
8750—8999	..	1	1	..	..	..	..
9000—9249	..	..	..	1	..	..	..
No. of cows	310		263		209		..
Means	3500	3838	3884	3912	4016	4069	4075
P. E. of means	∓51	∓52	∓59	∓58	∓64	∓69	∓80
Differences between means	+338	∓71	+28	∓83	—53	∓94	—154
Comparative yield	100·0	108·8	108·8	109·58	109·58	111·09	111·09

XV.

Individual cows, corrected yields.

number

5	5	6	6	7	7	8	8	9	9	10
1	1	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..
1	..	..	..	..	..	..	..	..	..	..
..	..	2	1	..	..	..	..	..	..	..
1	..	..	..	2	..	1	1	..	..	..
5	2	1	1	2	2	1	1	2	..	1
5	2	1	..	2	2	3	1	2	..	..
5	3	4	4	1	1	2	..	1	1	2
5	2	5	3	2	1	3	2	2	..	..
2	1	7	3	3	2	2	1	2	..	..
8	8	9	4	5	3	1	1	2	..	..
13	11	5	2	3	..	2	2	..	..	..
10	4	4	3	4	2	3	2	..	..	..
10	8	4	3	2	2	3	2	2	2	..
9	6	4	3	5	4	..	..	..	..	1
6	3	7	6	5	2	3	1	..	..	..
12	6	4	4	2	1	1	1	2	..	..
7	2	7	4	2	1	2	2	1	..	1
13	6	5	4	3	2	1	1	1	1	..
5	4	3	3	4	3	3	..	2	2	2
6	6	3	2	2	1	..	..	2	2	..
6	4	3	2	2	2	3	1	..	..	..
2	2	..	..	1	1	1	1	..	..	..
1	1	2	3	3	3	2	..	..	..	..
3	3	2	2	..	..	1	1	2	2	1
1	..	3	3	3	3	1	1	..	..	2
2	..	1	1	2	1	..	..	..	..	..
1	1	..	..	..	..	..	..	..	..	..
1	1	..	..	1	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..
..	..	1	1	1	1	..	..	..	..	..
..	..	..	..	..	..	1	1	..	..	..
..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..
141	8	7	6	2	4	0	23		1	0
3921	4030	3915	4193	4148	4318	3931	4040	3657	4800	4415
∓78	±96	∓105	±126	∓136	∓173	±173	±237	±212	..	..
±112	—115	∓142	—45	∓185	—387	±245	±383	±318	..	—385
106·89	106·89	103·83	103·83	102·72	102·72	93·51	93·51	84·65	84·65	77·86

The comparative means for the different ages as given in Table XV agree very well with those given in Table XIV, supporting thereby our first conclusion that there is not much of variation in S. P. with age. A close study of the actual means and the comparison of a succeeding mean with its preceding one for the same age also reveals the extent of selection on the basis of producing ability that has been going on in these herds. The means are quite regular, there being an increase in their value till the 4th lactation followed by a continuous decline, and the only thing required to be done is to smoothen down these means. To do this the precedence of Maine workers [Gowen, 1924] has been taken and a logarithmic curve of the form

$$y = a + bx + cx^2 + d \,/\log x$$

has been fitted by the method of moments [Miner, 1914-15].

The equation for the fitted cruve is

$$y = 100{\cdot}551 + {\cdot}911\,x - {\cdot}578x^2 + 25{\cdot}743 \log x$$

where x = age in lactations,

y = comparative yield on per cent. basis reduced to first lactation yield.

By differentiation of this logarithmic equation for milk yield, it was found that the maximum productivity of these cows occurs at the age of 3·524 lactations. The actual fit of the fitted curve to the observational means is shown in Figure 4, which shows that the fit is quite good and the actual comparative means as calculated from this theoretical curve together with the percentage correction that must be applied to the milk records produced at different ages to reduce them to the mature standard basis, *i.e.*, 3rd or 4th lactation are given in Table XVI.

TABLE XVI.

Corrections to total yield for age.

Age in lactations	% yield from smoothed curve	% to *add* to estimate mature yield
1	100·88	+9·5
2	108·05	2·4
3	110·36	..
4	110·45	..
5	108·65	+1·8
6	105·24	5·2
7	100·36	10·0
8	94·81	15·5
9	86·50	23·9
10	77·50	32·7

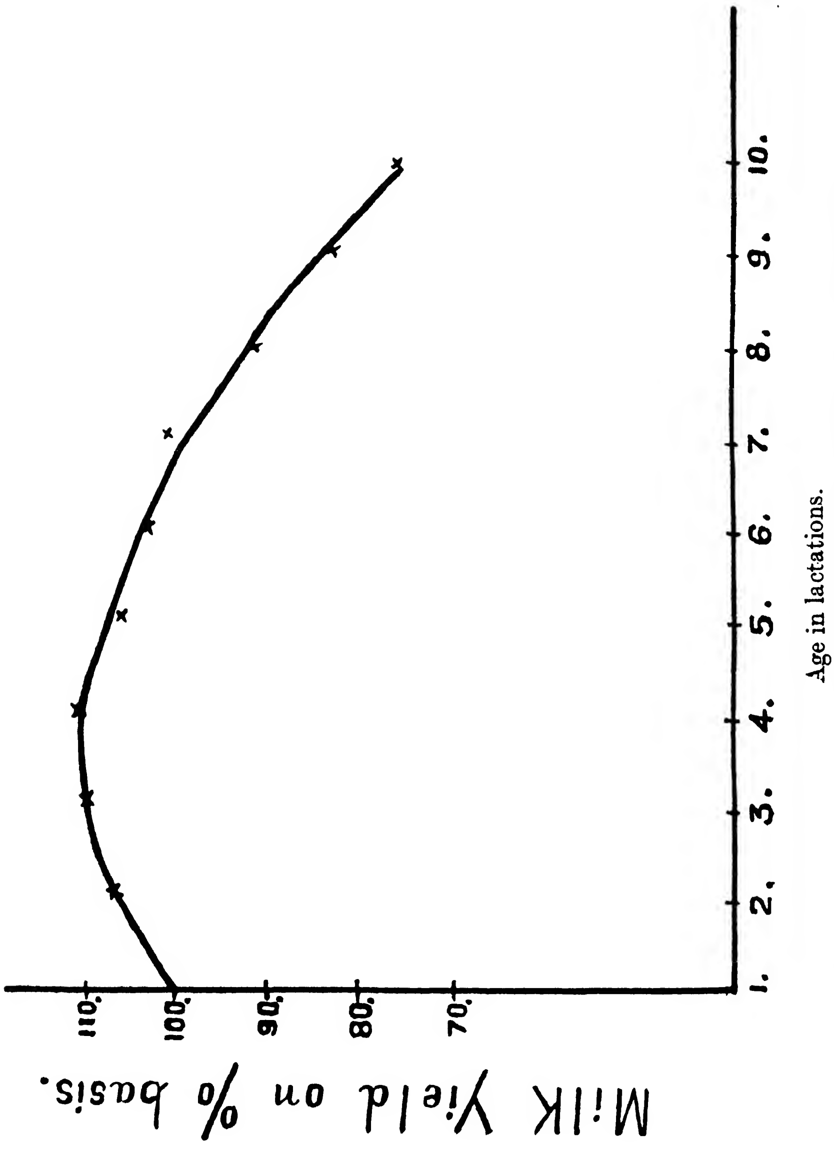


Chart 4. Variation of total lactation milk yield with age. (Pure breds).

It might be mentioned that the above results are absolutely in line with those of Maine workers, according to whom the milk yield rises at an ever decreasing rate as the age of the cow advances, until the age of maximum productivity is reached, from which age it declines at an ever increasing rate as age increases — a phenomenon which has been interpreted as an expression of growth and senescence.

Comparison of these results with those of other workers.

Table XVII gives our results for the variation of milk yield with age along with those of some other workers on the same subject.

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Table XVII.

Variation of milk yield with age.

Authority	Breed	Method of estimation	Comparative yields for :—							
			1	2	3	4	5	6	7	8
Sanders and Hammond	Cross-bred Shorthorn.	Composite curve.	100·0	110·3	118·5	125·1	130·4	...	...	...
Sanders .	Mixed . .	Do. .	100·0	113·2	121·7	128·1	131·7	132·7	130·8	125·7
McCandlish	Jersey . .	Lumped lactation.	100·0	107·2	121·8	134·7	141·9	146·2	148·7	152·5
Do. .	Guernsey .	Do. .	100·0	110·5	121·4	132·8	141·5	142·7	145·6	146·3
Gowen .	Jersey . .	Do. .	100·0	116·2	123·8	131·0	137·3	131·7	129·6	122·4
Do. .	Friesian .	Do. .	100·0	118·8	132·1	141·3	151·4	156·2	157·7	154·6
Kay and McCandlish	Ayrshire .	Successive lactation yields of same cows.	100·0	103·3	110·0	113·3	116·1	...	...	...
Gavin .	Shorthorn and Friesian.	Successive yields of same cows daily R. M.	100·0	130·6	146·9	156·1	161·2	163·3	161·2	161·2
Bangalore (Present paper).	Sahiwal .	Composite curve lactation yield.	100·0	107·1	109·4	109·5	107·7	104·3	99·5	94·0

A study of the above figures shows that not only do our cows reach the age of maximum productivity earlier than foreign cows and thence begin to decline rather

quickly, but that the total extent of increase in their milk yield as measured by the difference between the 1st lactation yields and the yield for the lactation of maximum productivity is very low. Roughly our average cow does her best performance at her 3rd lactation, and maintains this yield during the 4th lactation, whereas in no other case the maximum is reached before the 6th lactation ; furthermore whereas our cows increase to the extent of only about 10 per cent. of their 1st lactation yield till their maximum production ages the foreign cows increase by as much as 30 to 60 per cent. the variation depending upon the data used, *i.e.*, short period milk records, or lactation period milk records. All this goes on to prove the very poor quality of our Indian cows as milkers, for a good cow is a persistent milker not only in every lactation but throughout her life so that her average yield per lactation for whole life be high. This fact becomes all the more striking when it is borne in mind that the results as have been given above as representing the behaviour of Indian cattle are for the best Indian milch cattle, cows whose lactation yields are as high as 4,000 lbs. on the average and that much worse results would be got with the average Indian cows.

Of course, the peculiarity about the attainment of maximum production at a comparatively earlier age (as measured in lactations) in Indian cattle can be explained away by the fact that Indian cows calve about a year later than foreign ones, and the total period as covered by their 4 lactation periods is equal in length to that of 5 lactations of foreign cows, so that the actual age of maximum production (about 7-8 years for both) is more or less the same for both classes of animals ; but the other peculiarity, *i.e.*, the very low increase of yield of the lactation of maximum production over that of the 1st lactation, seems to the author to merit further consideration. However, it is not desired just at present to enter into the cause of this queer phenomenon. This, therefore, is left off for the present to be taken up in detail some other time though to check these results and to see if they truly represented the behaviour of all the cows of our data, the records as used above were divided into separate classes according to the number of lactations for which a cow was maintained in these herds, and the mean variation of milk yield was worked out separately for every class. No peculiarity however was observed in the behaviour of these various age classes as compared with the average results given above for all cows, except that the cows that were maintained for more than 8 lactations in these herds showed a higher increase till the age of their maximum productivity over the 1st lactation yield although they too increased till their 4th lactation only. This slight peculiarity, however, can be explained away by the fact that the animals included in these higher age classes are only selected ones ; and therefore the results already given in Table XVI seem quite correct and truly representing the underlying physiological relationships of the variations of milk yield

with age in our average pure-bred Indian milch cattle. That they are further confirmed by the experience of practical cattle breeders in India is seen from the Punjabee sayings " *Gán tije, mul na lije* " (never purchase a cow that is in her 3rd lactation) and *Gan Chauthe, Cham Othe* " (cow in her 4th lactation is merely a hide).

Cross-bred Indian Cattle.

To compare the behaviour of Indian cross-bred cows in this respect with that of pure-bred native stock, the variation of milk yield with age as exhibited in the cross-breds was worked out from the Pusa cross-bred stock. As mentioned before only 348 normal complete lactation milk records were available, and therefore the number of records included in different age classes, especially the older ones, was rather small. But since the results obtained are highly interesting and quite suggestive due to great regularity in their trend in spite of the very great paucity of data, they are given here, for they bring out very clearly the extraordinary milking capabilities of Indian cross-breds.

The procedure employed for study has been the same as used for the Sahiwals. Composite curve method was employed though only uncorrected records were used. The actual distributions are not given, but the fit of the theoretical curve to the observational means is shown in Figure 5, which as will be seen is quite fair.

The equation of the fitted curve is

$y = 79{\cdot}876 + 19{\cdot}748x - 1{\cdot}086x^2 - 28{\cdot}071 \text{ Log } x$ according to which the maximum is reached at $x = 8{\cdot}426$ as against $x = 3{\cdot}524$ for pure breds. The mean comparative yields reduced to the percentage basis together with corrections for age as calculated from this curve are given in Table XVIII.

Table XVIII.

Corrections for age for cross-breds.

Age in lactations	Comparative yield calculated from curve	Per cent. to add to estimate the mature yield (8th lactation)
1	98·54	+45·2
2	106·58	37·0
3	115·95	27·5
4	124·59	18·8
5	131·85	11·4
6	137·42	5·8
7	141·17	1·9
8	143·01	..
9	143·10	..
10	138·68	+4·5

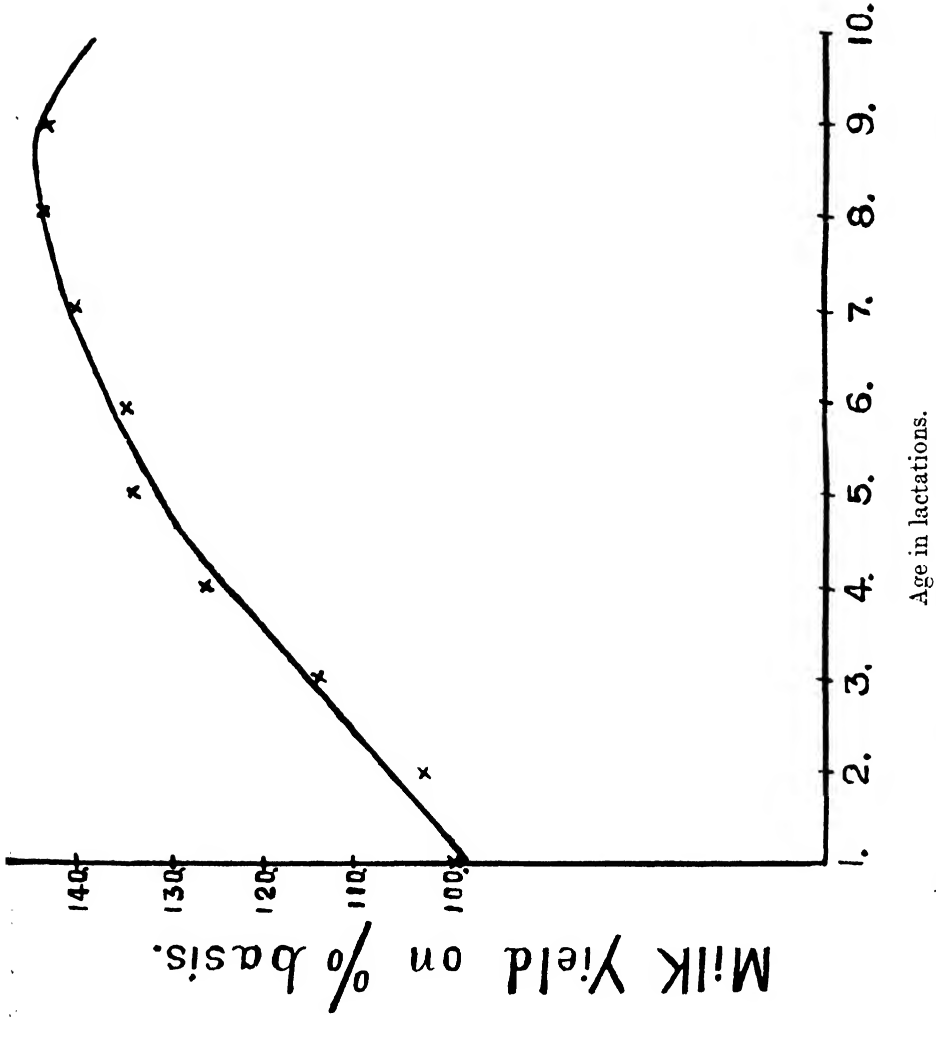

Fig. 5. Variation of total lactation milk yield with age. (Cross-breds).

A comparison of the comparative yields as given above for cross-breds with those of similar yields for other breeds as given in Table XVII shows that our Indian cross-breds are in no way inferior in their milking capabilities to any other breed. In fact the figures tend to show that if anything they are a bit superior to all others. This is perhaps due to the hybrid vigour. Since the results for the later ages are based on very few lactations, much reliance cannot be placed in their absolute value, but still the conclusion seems quite justifiable that the Indian cross-breds maintain their yields throughout their lives as nicely as any other dairy breed of the world. By this it is not meant to convey that as dairy animals cross-breds are as efficient producers of milk as any other dairy breed of the world. This can hardly be true, for their mean lactation yield is much lower than many a foreign breed. The only point stressed here is that they maintain their milk yields throughout their whole lives as nicely as any other foreign breed, and much better than pure-bred Indian stock and therefore are far superior to pure-bred Indians as milk producers. Whether they shall efficiently serve the work needs of the country it is not the purpose of this paper to discuss, but that they can play a very important role in solving Indian urban milk supply problem quickly is beyond doubt and is the purpose of this paper to emphasise.

Perhaps it is the recognition of this fact that has made the Military Dairy Farm authorities in the North to alter their plan of cattle breeding from one of selective breeding of pure-bred Sahiwals to that of grading them up with imported Friesian sires.

SUMMARY.

A statistical study of the lactation period milk yields of the cows of Sahiwal breed of India has been conducted with a view to study the variation as caused in them by and to standardize them against the effect of the season of year. S. P. and age, and it has been shown that :—

1. These pure-bred Sahiwals calve at intervals of about 13½ months. Out of this period they are dry for about 120 days, or about 29 per cent. of their life is useless. This is very high as compared with the same for foreign cows where the D. P. is generally only half as much.
2. Season of year does not seem to have any great effect on the total lactation yield in these records. This is because of the excellent system of herd management though due to paucity of data the results are not claimed to be final.
3. S. P. is a very potent factor in determining the lactation yield ; a short one depresses it and a long one increases it. Corrections are given for

different lengths of S. P. after calving, 85 days S. P. being chosen as the standard. These corrections agree very well with those of Sanders and Hammond [1923] for Penrith.

4. S. P. affects the total lactation yield by affecting the length of the lactation period.

5. The curve describing the function of variation of milk yield with age is logarithmic in nature, meaning thereby that lactation milk yield at first increases at an ever decreasing rate with increase of age till the age of maximum production, and from there it decreases at an increasing rate with advance in age.

6. The actual age of maximum productivity is roughly 3rd-4th lactation for pure-bred Sahiwals as against about the 6th for foreign ones, and approximately 8th for Pusa cross-breds. This earlier maturity of Indian cows is due to their age at 1st calving being a year higher and their lactation period being about two months longer on the average as compared with the foreign ones.

7. Separate correction tables are given for Sahiwals and cross-breds to standardize their milk records for age to mature standard basis, and a comparison made between these results with those for foreign cows. It has been shown that whereas foreign cows and Pusa cross-breds increase to the extent of 30 to 40 per cent. of their 1st lactation yield till their age of maturity, and then begin to decline, the *best average* pure-bred Indians increase by approximately 10 per cent. only. This is very important, for it proves the extremely poor milking qualities of Indian cows and the highly efficient nature of cross-breds as milk producers. It further emphasises how indispensable cross-breds are for the quick solution of the Indian urban milk supply problem.

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THE EXISTENCE OF FOWL TYPHOID IN INDIA *

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An outbreak of disease in a flock of poultry at Bhowali in the Kumaun hills was reported to this Institute in August 1930 when a dead fowl was forwarded for examination. Deaths took place in this outbreak mainly among adult birds and as single cases occurring over a period of about two months as shown in Table I.

TABLE I.

Date	No. of deaths in adult fowls	No. of deaths in chicks	Remarks
19th July 1930	1	..	
21st July 1930	1	..	
22nd July 1930	1	1	
30th July 1930	1	..	
3rd August 1930 . . .	1	1	
5th August 1930 . . .	1	1	
7th August 1930 . . .	1	1	
9th August 1930 . . .	1	..	*S. gallinarum* isolated in culture.
16th August 1930 . . .	1	..	
17th August 1930 . . .	1	..	
20th August 1930 . . .	1	..	
23rd August 1930 . . .	1	..	
Total .	12	4	

* Paper read at the 18th Session of the Indian Science Congress, Nagpur, 1931.

From the clinical history reported the disease was at first suspected to be fowl cholera and the use of serum and vaccine against this disease was advised. Bacteriological examination, however, subsequently showed that the outbreak was due to *Salmonella gallinarum*, Klein.

It is believed that the disease fowl typhoid due to this organism has not before been reported in India, and a further point of interest lies in the fact that outbreaks of disease in fowls may be wrongly diagnosed and thus account for failures from the application of serum and vaccine prepared for use against Fowl Cholera.

The disease was transmitted artificially at the laboratory to healthy fowls by the injection of culture of the organism isolated, and the course of the disease was then studied. Symptoms occurred from 2 to 10 days after injection (average 4·1 days) with one case later, on 18th day. They consisted of fever, ruffled feathers and impaired appetite with diarrhœa in some cases. Death occurred in 13 out of 16 fowls used, or 81·2 per cent. in 5 to 10 days with an average of 7 days. *Post-mortem* the lesions consisted of marked congestion of the internal organs excepting the lungs, and great enlargement of the spleen. In the first natural case examined *post-mortem* death was at least partly attributable to rupture of the liver resulting from extreme congestion of that organ.

Bacteriologically the organism isolated in this outbreak was indistinguishable from a "type" strain of *S. gallinarum* obtained from the Lister Institute, London, as shown in Table II.

TABLE II.

TABLE

Organism	Morphology	Cultural characteristics			Biochemical reactions		
		Plain agar slant	Plain broth	Potato	Gelatin	Litmus milk	Indol formation
Bhowali organism.	Non-motile rods 0·8 to 1·8 microns long, occurring singly or in short chains, sometimes showing peripheral but not bipolar staining. Gram negative.	Gray, moist, glistening colonies.	Turbid with sediment.	Grayish yellow growth slightly dry.	Not liquefied.	Very slight acidity followed by alkalinity.	Not formed.
S. gallinarum "type" English strain.	Ditto . .	Do.	Do	Do.	Do.	Do.	Do.
S. Pullorum "type" English strain.	Non-motile rods 1·0 to 2·5 microns long mostly occurring singly. Gram negative.	Discrete translucent, moist, glistening colonies.	Do.	Moist, deep grayish yellow, glistening.	Do.	—	Do.

A -
G =

II.

Carbohydrate fermentation														Identification
Dextrose	Lactose	Saccharose	Mannitol	Levulose	Galactose	Rhamnose	Arabinose	Maltose	Dulcite	Dextrin	Xylose	Inositol	Sorbitol	
A	—	A slight.	A	A	A	A	A	A	A	A	A	A	—	*S. Gallinarum.*
A		A slight.	A	A	A	A	A	A	A	A	A	A	--	*S. Gallinarum.*
AG	---	A slight	AG	AG	AG	AG	AG	---	—	--	AG	--	AG	*S. Pullorum.*

Acid.
Gas.
Unchanged.

Samples of serum obtained from fowls both naturally and artificially infected with the Indian strain of *Salmonella gallinarum* behaved in an identical manner when tested by the agglutination test against strains of *Salmonella gallinarum*, English and Indian, *Salmonella pullorum* and *B. typhosus*. Details are given in Table III.

TABLE III.

Serum from	History	Result of agglutination test against the antigen of			
		S. Gallinarum Bhowali strain	*S. Gallinarum* English strain	*S. Pullorum*	*B. Typhosus*
Rabbit No. 53 .	Injected with broth culture of virulent *S. Gallinarum*, Bhowali and bled after 10 days.	+	+	+	+
Rabbit No. 54 .		+	+	+	+
Fowl No. 97 .	Infected with broth culture of *S. Gallinarum*, Bhowali and bled after 13 days.	+	+	+	+
Fowl No. 90 .	Recovered after artificial infection with Fowl Typhoid 15 days after infection.	+	+	+	+
Fowl No. 143 .	Reported to have suffered from Fowl Typhoid and recovered in the outbreak.	+	+	+	+
Fowl No. 142 .		—	—	—	—
Fowl No. 144 .	Healthy controls . .	—	—	—	—
Fowl No. 123 .		—	—	—	—
Fowl No. 125 .		—	—	—	—

It is thus not possible, as has already been reported by a number of workers, to distinguish by the agglutination test between fowl typhoid caused by *S. gallinarum* and bacillary white diarrhœa caused by *S. pullorum*.

Dead bacterial culture was prepared for use as a vaccine, by growing the organism on agar plates, collecting the growth, emulsifying it in carbolised normal saline solution to opacity 8 by barium sulphate standard tubes and heating it at 65°C. for one hour. This vaccine, however, failed entirely to protect fowls inoculated with it against a small dose of the living organism given by subcutaneous injection. Details are given in Table IV.

TABLE IV.

Fowl No.	1st vaccination		2nd vaccination		Test with *S. gallinarum* living culture		Result
	Date	Dose	Date	Dose	Date	Dose	
23A.	29-8-30	1 c. c.	*Nil.*	*Nil.*	5-9-30	O. 5 c. c.	Died 4th day.
3A.							Died 6th day.
30A.							Died 8th Day.
53A.							Lived.
572A.	*Nil.*	Controls.					Died 2nd day.
585A.							Died 6th day.
586A.							Died 6th day.
12B.	29-8-30	1 c. c.	12-9-30	5 c. c.	19-9-30	O. 5 c. c.	Died 6th day.
523A.							Died 7th day.
588A.							Died 7th day.
15A							Recovered.
20A.	*Nil.*	Controls.					Died 4th day.
571A.							Died 22nd day.

Since, however, three fowls which were reported to have been affected and recovered from the natural disease in the Bhowali flock and one fowl which had recovered from artificial infection also succumbed to an injection of the same living culture, as detailed in Table V, it appears that the organism used for test purposes was so highly virulent as to break down both natural and artificial immunity. It is probable that vaccination might prove still to be of use, however, against natural infection.

Table V.

Fowl No.	History	Agglutination titre prior to the test	Infection with *S. gallinarum* living culture		Result
			Date	Dose	
90	Survived artificial infection and tested on the 14th day.	+			Died 15th day.
143	Said to have recovered from the natural disease at Bhowali.	+	5-9-30	O. 5 c. c.	Died 11th day.
142		—			Died 7th day.
144		—			Died 11th day.

Now that the existence of fowl typhoid in India has been proved, it is a matter of considerable importance to take steps at once to study the extent and distribution of this disease in India.

RANIKHET DISEASE : A NEW DISEASE OF FOWLS IN INDIA DUE TO A FILTER-PASSING VIRUS.*

BY

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(With 10 charts.)

The earliest mention of the disease described in this paper occurs in the Annual Report of the Muktesar Institute for 1927-28, where, under the heading "A New Fowl Disease," Dr. Edwards refers to an exceptionally heavy outbreak of disease in July, 1927, which accounted for about 400 highly bred fowls, within the brief space of two months, out of a flock of about 600 on a farm at Ranikhet, a neighbouring station to this Institute situated in the Kumaun foot-hills of the Himalayas. The two characteristic features of the disease stressed by Dr. Edwards were "the almost entire absence of lesions" and the non-inoculability of the virus with the blood of infected birds, although it was "readily conveyed with filterates of mouth-washings".

Towards the latter part of 1928, the disease was diagnosed in a number of sick fowls forwarded to this Institute by a private poultry-owner in the Garhwal district of the United Provinces. Again, in January and April of last year. 1929, the disease occurred in two separate outbreaks on the farm of the United Provinces Poultry Association at Lucknow, and the identity of the disease in one at least of these outbreaks with "Ranikhet Disease" was confirmed from examination of infected fowls at the Muktesar Laboratory.

Infective material thus became available at this Institute from each of the three outbreaks referred to above, and advantage was taken of the opportunities thus afforded to carry out a study of the disease under laboratory conditions.

A brief reference to this work was included by the writer in the Annual Report of the Muktesar Institute, 1928-29, and the present paper includes results obtained since 1927 from the study, which is still in progress.

Outbreaks of what would appear to be the same disease—for its identity can hardly be mistaken despite the frequently meagre clinical details available—have also been reported from a large number of widely separated localities in India, and even appeals for help in combating the outbreaks have been noticed in the correspondence columns of Indian newspapers.

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*Paper submitted to World Poultry Congress, 1930.

A fact of some considerable interest in connection with these natural outbreaks of the disease is that in many of the reports it is stated that crows were noticed to be dying in very large numbers in the vicinity of poultry farms when the disease was raging at the time among poultry upon the farms.

Isolation of Infective Material.

Trials with mouth-washings, emulsions of internal organs and with blood from infected birds soon showed that whilst the first two proved infective when injected under the skin of healthy fowls, the inoculation of blood in this manner sometimes failed to produce infection. Also, the virus proved capable of passing easily through fine bacterial filters ("L 3" candles fitted to Martin's filtering apparatus). In the earlier experiments, the infective material used in the artificial production of the disease consisted entirely of mouth-washings, but latterly it was supplanted by organ emulsion on account of the ease with which the latter could be kept alive under laboratory conditions. The preservation of the organ emulsion was carried out on the lines indicated by Doyle [1927] in his report upon the so-called "Newcastle Disease," use being made for the purpose of a mixture of the main cellular organs of the body, liver, spleen and kidneys. The organs were removed with strictly sterile precautions from fowls destroyed at the commencement of the disease, subjected to a process of desiccation, and stored, without the addition of any preservative, in a refrigerator at a temperature below 4 degrees Centigrade. As would appear from the following Table, when stored in this manner the material proved definitely infective for 125 days, and probably until 169 days, in spite of the fact that in a few instances it was noticed to have developed contaminating growths of mould.

Age of virus days	No. of fowls tested	Fowls died "Ranikhet disease"	Fowls died undiagnosed	Fowls lived	Survivors re-tested with virus
87	2	2	—	—	—
91	2	2	—	—	—
95	2	1	1	—	—
101	2	2	—	—	—
105	2	2	—	—	—
111	2	1	1	—	—
115	2	2	—	—	—
121	2	1	1	—	—
125	2	1	—	1	No reaction. Immune.
147	2	—	—	2	Reacted and lived partly immune.
151	2	—	—	2	Reacted and died.
155	2	2	—	—	—
169	2	—	2	—	—

The virus contained in this material has been maintained for over a year at the laboratory by passage occasionally through fowls, and the reactions exhibited in fowls injected with it have been identical in every respect with those provoked by mouth-washings.

Reproduction of the Disease.

A very large number of healthy fowls has been utilized during the course of the work undertaken at this Institute, but examination of 113 records of birds used in a series of 56 direct passages, where virus in the form of filtered mouth-washings was employed, will serve as an indication as to the extent to which country-bred fowls are susceptible to this affection. The number of fowls actually used in this series was greater than 113, but all records of fowls which were destroyed in the course of the experiments for various reasons, and where complications interfered with the normal progress of the disease, have been excluded from the present note. The results of experimental observation upon these 113 fowls may be summarised as follows :—

Reacted and died	96 fowls or 85·0 per cent.
Reacted and recovered	11 fowls or 9·7 per cent.
No appreciable reaction	6 fowls or 5·3 per cent.

The following Table shows the days after virus injection on which the 96 fowls referred to above first exhibited symptoms, and the days also on which death occurred.

—	Days after injection of virus																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Number of fowls showed first symptoms .	0*	0	12	30	30	15	3	2	0	0	2	1	0	0	1	0	0	0	0	0	0
Number of fowls died	0*	0	2	20	24	17	9	8	3	2	3	3	2	0	0	1	1	0	0	1	0

It will be seen from the above table that in artificial infection the incubation period is between 2 and 14 days although by far the largest number of birds developed the disease within 5 days of inoculation, so that virtually the incubation period can be said ordinarily to be from three to five days, since only seven fowls showed a "delayed reaction" from the 6th to 14th days, and the 12 reactions which occurred as early as the second day nearly all took place at one period during the sub-inoculations, indicating a distinct increase in virulence at that time due to rapid passage. The average period of incubation was just over 3½ days.

* 0th day, or day of injection of virus.
Average (1) incubation period, 3·55 days; (2) duration of illness, 1·55 days.

Death occurred in most cases almost immediately the first symptoms were shown, that is, on the same day or only one day later. Two birds thus died on the second day, and the largest number died on the 3rd and 4th day after injection.

The periods of recognisable illness before death occurred are given in the following table, which shows that death occurred on the day the first symptoms were exhibited in nearly one-third of the fowls; in over one-third it occurred only one day later, and the maximum duration was 10 days. The average duration of recognisable illness in the 96 fowls therefore amounted to only just over one-and a-half days.

Death	Number of fowls	Total days
On day of first symptoms	30	0
1 day later	35	35
2 days later	12	24
3 „ „	8	24
4 „ „	3	12
5 „ „	3	15
6 „ „	1	6
7 „ „	1	7
8 „ „	2	16
9 „ „	0	0
10 „ „	1	10
Total .	96	149

Average duration of illness, 1·55 days.

The eleven birds which showed a definite reaction and recovered exhibited symptoms as follows:—

—	1	2	3	4	5	6	7	8	9	10
Day of first symptoms	—	—	1	—	5	4	1	—	—	—
Duration of symptoms in days	1	1	2	2	1	1	—	—	—	3

Symptoms of the Disease.

The nature of the reaction exhibited after artificial infection is illustrated in charts Nos. 1 to 8. From these it will be seen that the birds remain apparently unaffected until suddenly the temperature drops to a marked degree; the fowls then become very dull, go off their feed and die often before any further symptoms are exhibited. The fall in temperature was the most striking and characteristic symptom of the disease, although in a few instances this was immediately preceded by an elevation in the temperature, as illustrated in charts Nos. 6 and 7. Occasionally birds died suddenly before any apparent disturbance in the temperature curve was exhibited, as illustrated in chart No. 4. Chart No. 9 is that of a fowl which contracted the disease naturally while under observation at Muktesar, and is included for comparison. It will be seen from this chart that the symptoms of the naturally contracted disease are very similar in all essential details to those observed in the artificially induced infection.

Symptoms which were exhibited inconstantly, and which are seen usually, it is understood, in the disease as it occurs under natural conditions, are marked respiratory distress, without, as is noted below, any *post-mortem* pathological lesion in the lungs; a profuse discharge from the beak and nares associated with a very offensive odour arising from decomposition of the contents of the crop; diarrhœa; marked weakness of the limbs so that affected fowls are unable to keep on their legs, and in chronic cases inco-ordination of the head and neck is seen. This last symptom has been observed in a few fowls which have recovered from the disease. They stand with the head bent backwards, often appearing to be normally at rest with the head under the wing but when disturbed the head and neck are raised and marked inco-ordination is exhibited, the head being waved in the air with irregular circular motions. With extreme difficulty birds are then able to pick up food, but nevertheless birds which have otherwise recovered have been kept under observation at this Institute for many weeks exhibiting this disability to a very marked degree. Paralysis otherwise has not been observed to be a marked symptom in experimentally induced Ranikhet disease in fowls.

Post-Mortem Appearances.

Except for an excessive quantity of saliva, or exudate, in the buccal and pharyngeal region, associated with a highly disagreeable odour, and possibly emaciation in the more prolonged cases, the only lesions that can be referred to as characteristic of the disease are discrete petechiae or ecchymoses found typically in the submucosa of the proventriculus, but also occurring occasionally in other positions in the digestive tract and very rarely in other organs, such as the lungs and peritoneum. A localized catarrhal enteritis is not infrequently seen in one or other of the following positions; duodenum, caeca or cloaca. In the most acute and

rapidly fatal cases the carcase upon *post-mortem* examination often appears indistinguishable from that of a healthy fowl. The most striking fact is the complete absence of any recognisable lesion in the lungs of birds which have exhibited perhaps extreme respiratory distress during life.

Control Measures.

Research work undertaken at this Institute under the above head has been confined almost entirely to the laboratory, and the application of control measures in natural outbreaks of the disease has not yet been attempted on any large scale by us.

In view of the tenacious nature of the viability of the virus, it is remarkable that the disease was controlled with both speed and effectiveness in the two outbreaks which occurred last year upon the farm of the United Provinces Poultry Association at Lucknow, referred to earlier in this paper. The flock on this farm comprised as many as 1,300 valuable pedigree birds, and were it not for the prompt and energetic measures adopted by Mrs. Fawkes-Ansell, the Secretary of the Association, in combating the outbreaks, the percentage of mortality amongst the birds exposed to infection would doubtless have run to a high figure. Yet the measures consisted only in destruction of the fowls exhibiting symptoms, addition of permanganate of potash or iodine to the drinking water and food of all non-affected birds, and the liberal use of phenyle compounds in the houses and pens. Upon both occasions the disease was stamped out immediately, with the loss only of the affected birds sacrificed. Experiments have recently been carried out in this Institute upon the possibility of controlling the disease by the application of (1) serum derived from fowls that had recently recovered from the artificially induced disease; (2) serum prepared from donkeys injected with "Ranikhet disease virus" and (3) vaccine prepared from organs of diseased fowls.

(1) The results of a preliminary test with the fowl serum are shown in the following table:—

Fowl No.	Serum	Days of symptoms	Result
30	5 c. c.	? 4th	Lived. Re-tested, 59th day, ? *reacted*—Lived.
31	5 c. c.	4th to 8th	Recovered. Died 60th day, ? *relapse*.
32	2 c. c.	5th to 9th	Recovered. Died 50th day of Debility.
33	2 c. c.	7th	Died 9th day.
34	Nil (Controls)	4th	Died 4th day.
35	Nil (Controls)	4th	Died 7th day.

A further test upon the immunizing effect of serum derived from recovered fowls has just been completed at the moment of writing this paper (January 1930), and the results of this test are summarized in the table below. In all cases the birds were injected with virus 24 hours after the injection of serum.

Dose of serum	Fowl No.	Reaction	Day of death	Result
10 c.c. . . .	508 509			
5 c.c. . . .	510 511 512 513	Just appreciable fall in temperature on 2nd day only.	All survived.	Immun.
2·5 c.c. . . .	514 515 516 517			
Nil (controls) . .	520 521 519 518	3rd day 4th day 5th day 5th day	4th night 5th day 5th night 7th night	All fully susceptible.

The records of the ten fowls used in the above test are represented in the composite chart No. 10, which shows that a slight but distinct fall in temperature—apparently indicating a reaction—occurred on the second day after virus was injected.

(2) In view of the distinctly positive results following the use of fowl serum, the completely negative results obtained when attempting to produce an anti-serum upon a large scale from donkeys has been very disappointing. In 1926, an anti-serum derived in a similar manner from donkeys had been found by the writer to be of some value against spirochaetosis of fowls (due to *Spirochaeta anserina*). In the present series of experiments, in spite of the encouraging fact that a distinct reaction occurred in the donkeys, even when filtered mouth-washings alone were given intravenously as virus, the serum derived from these animals proved to be of no value whatever when tested as to its protective value upon fowls against "Ranikhet disease" virus.

(3) A vaccine was prepared from organs of diseased fowls after treatment with chloroform, on the lines introduced by Kelser [1928] as a protective agent against

rinderpest or cattle plague, but this proved to be equally valueless upon trial in "Ranikhet disease". It is of interest to note that in one experiment the virus definitely survived the treatment with chloroform although this is held to be capable of rendering the virus of cattle plague inert.

IDENTITY OF "RANIKHET DISEASE".

Since 1927, a not inconsiderable number of articles upon what would at any rate appear to be closely related to "Ranikhet disease" have appeared in scientific publications from many parts of the world. Of these mention may be made of "Newcastle Disease" in England [Doyle, 1927]; "Avian Pseudopest" in Java [Picard, 1928]; "Avian Pest" in the Philippine [Rodier, 1929]; "A New Malady of Fowls due to a Filter-passing Virus" in Egypt [Lagrange, 1929]; and "A New Poultry Disease" ("Geflugelseuche") in Korea [Ochi and Hashimoto, 1929].

The results of early work which was in progress at this laboratory at the time of the publication of Doyle's article [1927] had already suggested to Major R. F. Stirling, then Officiating Pathologist at this Institute, the very considerable similarity that appeared to exist between "Ranikhet disease" and "Newcastle disease." The results of experiments carried out subsequently by the present writer have now furnished him with definite confirmatory evidence indicating a very close similarity between the two forms of affection, as noticeable in their contagious nature; the high rate of mortality amongst affected birds (in the case of "Newcastle disease," Doyle estimates a mortality rate of about 100 per cent.); the infectivity of the internal organs and mouth exudate of diseased birds; filterability of the virus; the not infrequent non-inoculability of the virus with blood; the respiratory symptoms; and in the *post-mortem* findings, *e.g.*, the occurrence of localized catarrhal enteritis in the duodenum, caecum or cloaca. On the other hand, the almost consistent absence of febrile symptoms in "Ranikhet disease" constitutes a notable point of difference between this and "Newcastle disease," whilst the average incubation period in the latter affection, as given by Doyle, is also slightly longer than that observed in "Ranikhet disease."

A striking proof that "Ranikhet disease" is, at any rate, immologically identical with "Newcastle disease" of England and also with "Avian pest" in the Philippine Islands has been afforded by a comparative test of the three viruses at Muktesar.* It will be observed from the results summarized in the table

* The writer desires to express his sincere gratitude to Dr. Rodier, Pathologist, Veterinary Research Laboratories, Minala, for providing him with samples of the viruses of both "Newcastle disease" and "Avian pest," the former having been previously obtained by Dr. Rodier from England from Mr. Doyle. These samples were despatched to the writer in India in cold storage all the way from Manila, and the courtesy with which Dr. Rodier has attended to the writer's requests in this connection is eloquent of the spirit of co-operation existing amongst veterinary workers overseas.

below that, while fowls that had recovered from an attack of "Ranikhet disease" were solidly immune to each of the other two viruses, healthy fowls were fully susceptible to them. Conversely, fowls that had recovered from an artificially induced attack of "Newcastle disease" proved fully resistant to the virus of "Ranikhet disease".

Susceptibility of Birds other than Fowls to Indian, English and Philippine Viruses.

At the time of completing the writing of this paper, the results of inoculating pigeons with the three viruses referred to above are becoming apparent. The reaction exhibited is similar to that occurring in fowls, except that in the pigeons now under observation paralysis of the legs and wings is an extremely well marked symptom.

It is hoped that it will be possible to submit an addendum to this paper detailing the final results of injection of the viruses into pigeons as well as into some other birds.

Summary and Conclusions.

1. The disease described in this paper was first recognised in India in 1927.

2. It is an acute, usually non-febrile, contagious and highly infective disease of fowls, caused by a filter-passing virus and characterised by respiratory distress and high mortality.

3. Reports have frequently been received of heavy mortality occurring amongst the crow population of infected localities.

4. The incubation period in the artificially produced disease is ordinarily from 3 to 5 days, but may be as short as 2 days or delayed until the 6th or 7th, and exceptionally even the 14th day.

5. The duration of recognisable illness in the artificially produced disease is usually extremely short, averaging only 1½ days, but the period may extend to ten days.

6. Ninety-five per cent. of Indian country bred fowls used in transmission experiments proved to be susceptible to the virus and only ten per cent. of the affected animals survived.

7 Except for the occurrence of petechiae in the submucosa of the proventiculus, *post-mortem* lesions of diagnostic value are almost entirely absent.

8. Emulsion of internal organs stored unpreserved in a refrigerator have been proved to retain their infectivity for periods extending to 169 days.

9. Serum obtained from recovered fowls is protective against the disease, but serum produced from donkeys proved to have no protective value.

10. A few attempts were made to prepare a vaccine suitable for employment against the disease, but they were unsuccessful.

11. The disease had been shown to be immunologically identical by cross-immunity tests with both "Newcastle disease" in England and "Avian pest" in the Philippine Islands.

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TABLE.

Results of a comparative virus test carried out on 9th September, 1929.

Virus			Fowls		Test		Retest with Indian Virus		Result
Source	No.	Date	History	No.	Reaction	Day of Death	Reaction	Day of Death	
English Newcastle disease	1	1-8-29	Healthy . .	247 248	*Nil* *Nil*	Lived Lived	4th day 3rd day	4th 7th	Virus dead.
			Recovered from Ranikhet disease	96 109	*Nil*	Lived	—	—	
	2	6-8-29	Healthy . .	249 250	4th day 6th day	6th 13th	— —	— —	Virus alive. Recovered fowls immune.
			Recovered from Ranikhet disease	30 110	*Nil*	Lived	—	—	
Philippine Avian pest	3	1-8-29	Healthy .	241 242	? ?	4th Lived	— *Nil*	— Lived	Virus ? alive.
			Recovered from Ranikhet disease	182 191	*Nil*	Lived	—	—	
	4	5-8-29	Healthy . .	243 244	5th day *Nil*	8th Lived	— 3rd day	— 4th	Virus ? alive.
			Recovered from Ranikhet disease	14 150	*Nil*	Lived	—	—	
	5	5-8-29	Healthy . .	245 246	4th day 4th day	5th 6th	— —	— —	Virus alive. Recovered fowls immune.
			Recovered from Ranikhet disease	157 160	*Nil*	Lived	—	—	
Indian Ranikhet disease	6	27-7-29 and 27-8-29 (mixed sample)	Healthy . .	239 240	4th day 3rd day	4th 3rd	— —	— —	Virus alive. Recovered fowls immune.
			Recovered from Ranikhet disease	185 18	*Nil*	Lived	—	—	

Passage of Ranikhet Disease Virus.

Fowl No. 81.
Injected Virus 15-4-29.

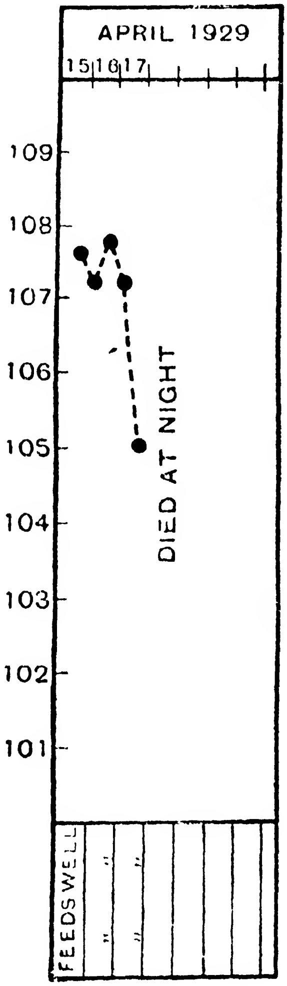

Chart 1.

Fowl No. 34.
Injected Virus 8-12-28.

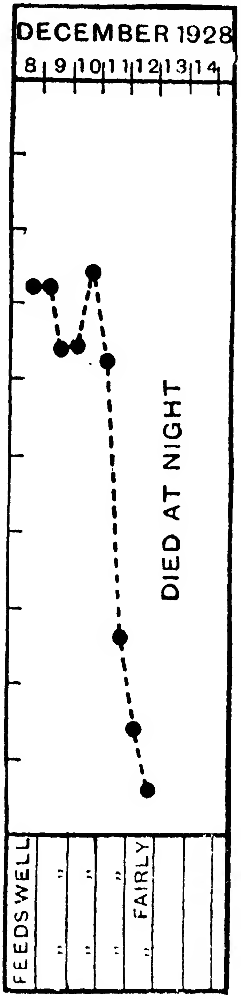

Chart 2.

PASSAGE OF RANIKHET DISEASE VIRUS.

Fowl No. 74.
Injected Virus 22-12-28.

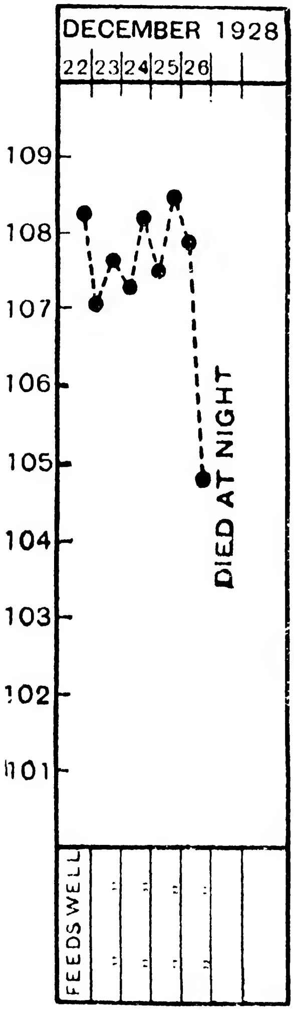

Chart 3.

Fowl No. 25.
Injected Virus 20-11-28.

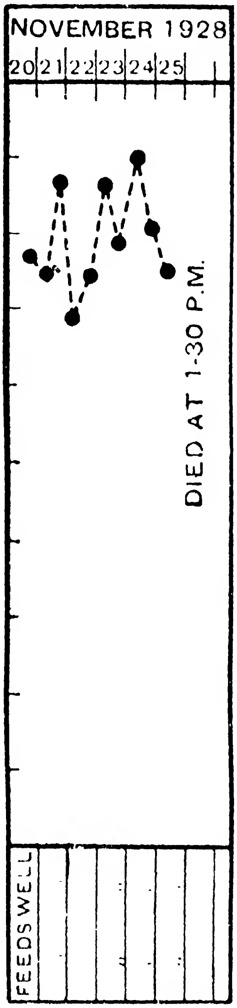

Chart 4.

PASSAGE OF RANIKHET DISEASE VIRUS.

Fowl No. 6.

Injected Virus, 5-1-29.

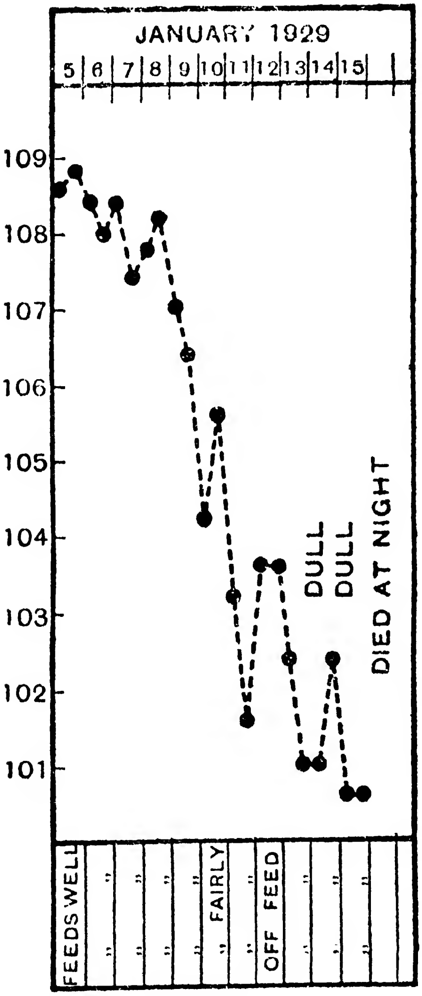

Chart 5.

Fowl No. 56.

Injected Virus, 15-3-29.

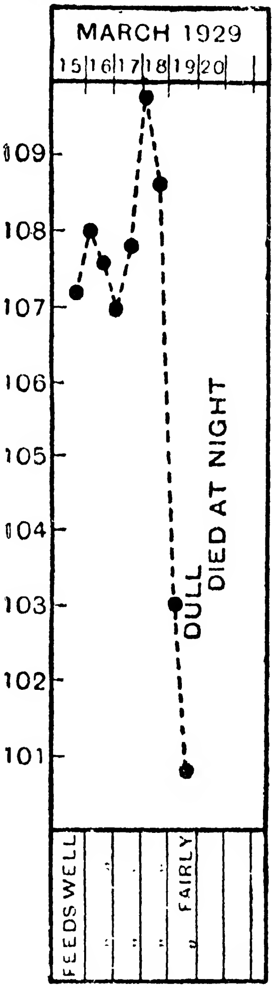

Chart 6.

Passage of Ranikhet Disease Virus.

Fowl No. 39.
Injected Virus 16-11-28.

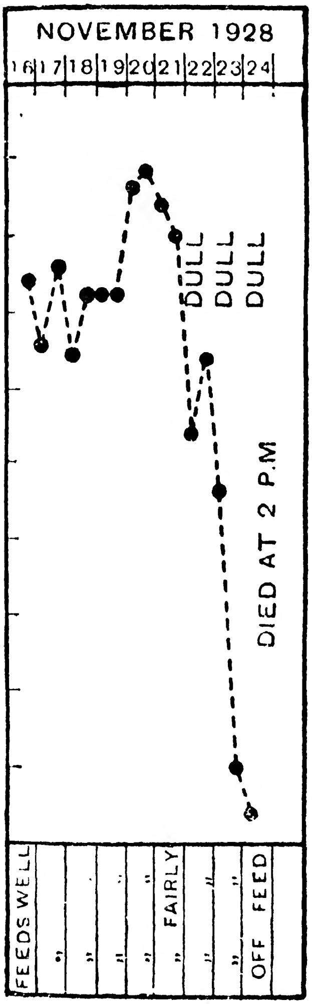

Chart 7.

Fowl No. 56.
Injected Virus 8-12-28.

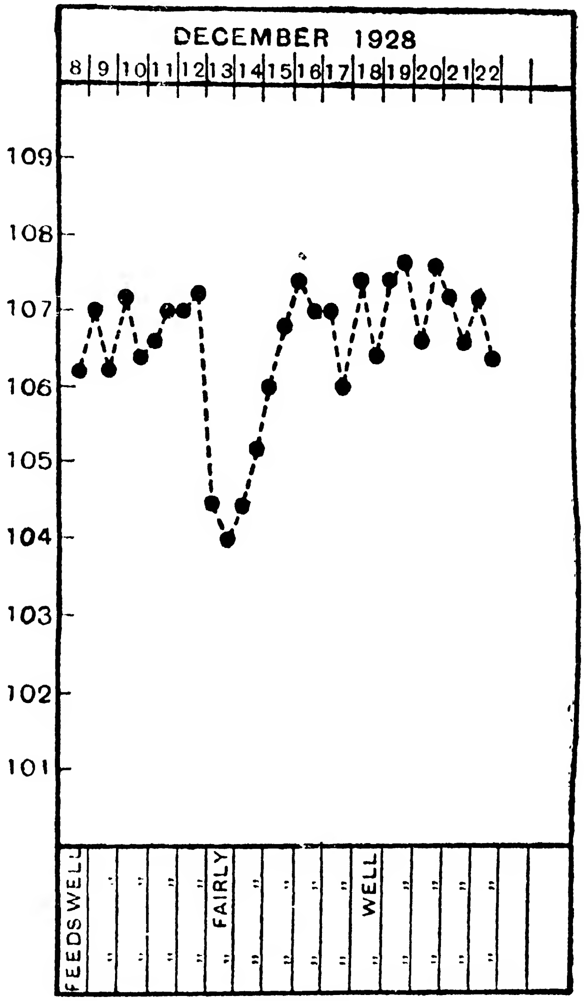

Chart 8.

NATURAL CASE IN HEALTHY FOWL UNDER OBSERVATION.

Fowl No. 24.

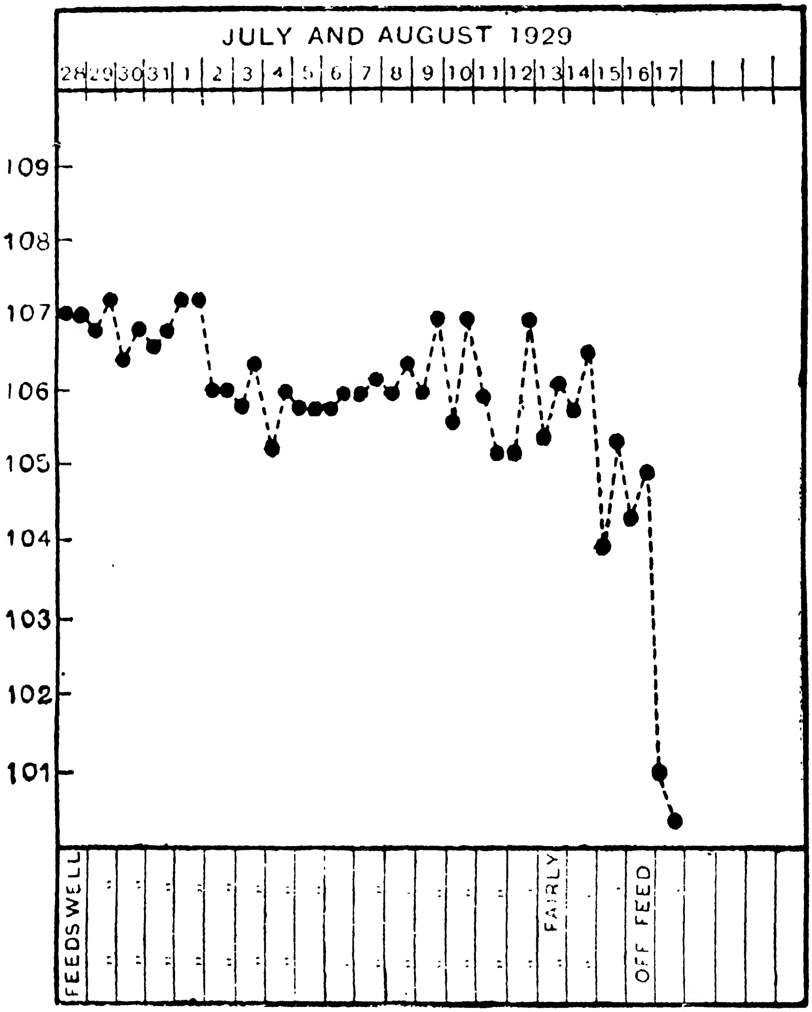

Chart 9.

Composite Chart of Ten Fowls given Serum drawn from Recovered Fowls on 7-1-30, and Ranikhet Disease Virus on 8-1-30.

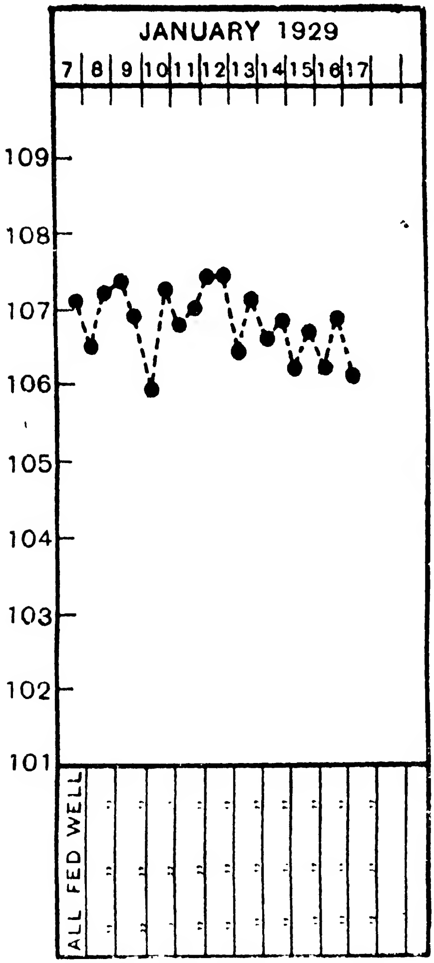

Chart 10.

PRACTICAL FEEDING TABLES FOR DAIRY CATTLE IN INDIA.

BY

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It is essential, in these days, when science and business working together have made "Standardization" the main road to commercial success, that dairy farmers should also keep abreast of the movement. Of all the processes on a dairy farm, perhaps, the art of feeding cattle is the most difficult to standardize.

The factors involved are numerous, many vary from day to day, and although an immense amount of scientific help, in the shape of data based on accurate research work, is available, much of this data may be most misleading when applied to local conditions.

In putting forward these tables, I, therefore, do so with diffidence and only claim that they fulfil three conditions, which *inter alia*, are in my opinion, essential in any system offered to the ordinary farmer, namely :—

(1) They take into consideration the main factors involved in feeding cattle.

(2) They are simple, as they require the minimum amount of calculations at infrequent intervals.

(3) They can be easily modified to suit local conditions and the increasing experience of the feeder.

It is not possible, in a paper of this description, to examine all the data on which these tables have been based. I shall, therefore, merely, briefly discuss the main factors a farmer has to consider when computing rations for his animals and how these factors have been allowed for in these tables.

1. FEEDING VALUE OF FOODS BEING USED.

For the ordinary farmer to obtain accurate analyses of the various foods he is feeding is not practicable. This applies especially to fodders, which form the bulk of his rations. Fodders, even of the same varieties, differ greatly in feeding value depending on such factors as the soil and climate in which grown, time of cutting, etc.

In these tables fodders have been divided into four categories ; these have been found sufficient in Northern India without making the tables too complicated.

The quantity of concentrate mixture is fixed to bring the feeding value of the entire ration up to what is at present considered the most economical standard for the various animals. These figures are based on feeding for the past 6 years, over 3,000 animals scattered over the Punjab, North-West Frontier Province and Baluchistan.

2. Work performed by the Animal.

It is economical to feed individual animals according to the work they perform. See Tables B and D.

3. Size of the Animal.

The surface area of an animal has a very direct bearing on its food requirements. This is most easily allowed for by weight. Weight also plays an important part in checking the efficiency of a ration, especially for calves. See Tables A, B, C and D.

4. Period of Pregnancy.

The nourishment of the growing foetus calls for little extra food until the last few months of pregnancy. It is, however, important that the animal should be in good condition when calving, as this has an appreciable effect on its subsequent yield during the lactation. See Table C, where an allowance has been made for pregnant cattle from "3 months to calve" onwards.

5. Climate.

It has been found that cattle need extra ration during the winter months in some parts of India. See Table E.

6. Mineral Requirements of Cattle.

This question is still to some extent in the experimental stage. See Table F.

7. Individuality of the Animal.

Never mind what system of feeding is devised to suit the average animal, there will be certain individuals which it will, obviously, not suit. Such animals must be given special attention and their rations altered accordingly if economical to do so, otherwise they should be cast. See (8).

8. Condition of the Animal.

For the intelligent application of any system it is essential that the farmer should continually study the condition of his cattle; this will give him a good indication as to whether he is, or is not, feeding correctly.

At least once a week he should go round his herd and after carefully inspecting each animal mark up its condition. See Ration Statements I and II (5).

9. Percentage of Fat in the Milk.

Most authorities make an allowance in the ration for the percentage of fat in the milk. I do not think it is worth the trouble involved in India. The marked difference between the percentage of fat in cows' and buffaloes' milk, appears to be compensated for best by an increase in fodder for buffaloes; these animals have a remarkable capacity for utilising fodder and thrive better on a wider nutritive ratio than cows.

I must acknowledge the many valuable suggestions which I have received from time to time and which are embodied in these tables from Mr. H. B. Claxton, Deputy Assistant Controller, Dairy Farms, Managers of Military Dairies in the Northern Circles, and from Mr. Balwant Singh, M.Sc., Agricultural Research Chemist, Military Farms Department.

Conditions necessary for the successful working of these tables.

To work these tables—in fact any system of scientific feeding—the farmer must carry out the following :—

(a) Weigh the concentrates to be given to each animal.

(b) Weigh the fodder to each group of animals receiving the same fodder scale. Individual weighment to heavy yielders.

(c) Feed the concentrates dry. This is almost essential if each animal is to receive its correct weight of concentrates at each meal.

(d) Ensure that an animal is not robbed by its neighbours. If proper standings and troughs, which fulfil this condition, cannot be provided, then animals must be fed in buckets.

(e) Compute correctly the quantity of ration each animal should receive; to do this the farmer must maintain these records :—

i. Daily, or at least weekly, milk records.

ii. Register of services (Appendix III).

iii. Register of weights. The following weights should be recorded :—

a. Calves :—At birth and then weekly till 9 months old.

b. Young Stock (9-18 months) :—Every two months.

c. Animals over 18 months :—

1. Milking herd. Every lactation a week after calving.
2. The rest every year.

NOTE.—In the case of farmers who do not possess, or cannot obtain the use of a weighbridge, for weighing large animals, approximate weights may be arrived at by measurement as follows :—

$\text{girth}^2 \times \text{Length} \times 5{\cdot}5 = \text{live weight in pounds}$.

The length of an animal is taken straight along the back from the square of the shoulder to the square of the buttock and the girth immediately behind the shoulder.

The measurement should be taken in feet.

iv. Ration records.

For the information of the farmer who has never maintained such data before, and is, therefore, rather doubtful as to the type of form in which this data should be recorded, I have given a sample of some forms as appendices.

THE CONCENTRATE MIXTURE.

The concentrate mixtures are fixed for the figures in the tables as follows :

Table A. 1 part crushed oats, 1 part finely ground linseed cake, and 1 part wheat bran.

Tables B, C, D and E. 4 parts wheat bran, 2 parts ground *toria* cake, 2 parts gram husk, 1 part gram.

In certain localities some other mixture may be more economical and it is obvious that if mixtures very different in feeding value are fed, instead of the mixtures above, then the figures in the tables will require alteration accordingly.

A farmer making up a concentrate mixture, to suit his locality, should ask himself the following questions concerning the ingredients :—

(*a*) Are they palatable ?

It is advisable to only feed cattle on foods they will eat readily. Often, however, foods disliked by cattle when first given, are later on relished when they have developed a taste for them.

(*b*) Are they obtainable throughout the year ?

Except in very special circumstances, it is more satisfactory to make up the concentrate mixture from foods available throughout the year. Provided a concentrate mixture is suitable, it is a mistake to change it frequently, as most changes, even if theoretically beneficial, in practice bring about a reduction in milk yields for a certain period.

(c) Are they of sufficient variety ?

It is safer to feed at least three different foods in the concentrate mixture. By different foods I mean foods from different sources; for example, linseed cake and gram are different foods but not wheat bran and wheat.

(d) What is their local cost in relation to their feeding value ?

The feeding value of one food in comparison with another even when only considering dairy cattle, is a question on which there is much difference of opinion. I, however, give some figures in Table 1 which may help the farmer in making up his mind as to what to feed.

Table 1 will also be found very useful in making corrections in the "Feeding Tables" without too many calculations.

For example, if instead of 4 parts wheat bran, 2 parts *toria* cake, 2 parts gram husk and 1 part gram, a farmer wishes to feed 3 parts linseed cake, 1 part barley, 2 parts wheat bran and 3 parts gram husk, he would make the following calculations:—

4 Wheat bran	$= 4 \times 43 = 172$	units.
2 Toria cake	$= 2 \times 65 = 130$	,,
2 Gram husk	$= 2 \times 35 = 70$	,,
1 Gram	$= 1 \times 68 = 68$	,,
	9) 440	
1 lb. approximately	48·9	
3 Linseed cake	$3 \times 74 = 222$	units.
1 Barley	$= 1 \times 71 = 71$	,,
2 Wheat bran	$= 2 \times 43 = 86$	,,
3 Gram husk	$= 3 \times 35 = 105$	,,
	9) 484	
1 lb. approximately	53·8	

That is, approximately 10 pounds of the standard mixture is equal to 9 pounds of the new. All figures in the tables should, therefore, be multiplied by 9 and divided by 10.

In revising the Feeding Tables the farmer should only work to the nearest pound.

In Table 1 it will be noticed that the feeds are divided into 3 categories and it has been advised that only a certain percentage of each category should make up the total mixture. This has been done to ensure a sufficiency of digestible protein in the mixture. When the fodder is leguminous, these restrictions may be relaxed to some extent. In India, however, protein is comparatively cheap, therefore, a ration containing only the minimum protein requirements may not be the most economical one.

A certain quantity of wheat bran should be a feature of all mixtures fed to the milking herd as it is an excellent feed for such animals, and at the price at which it is usually available in India, good value for money.

TABLE 1.

Food stuff	Unit value	Category No.	Minimum and maximum percentage of each category which should be in final mixture: Not less than	Not more than
			%	%
Linseed cake	74	I	30	60
Til cake	72			
Toria cake	65			
Cotton seed	63			
Mustard cake	61			
Gram	68			
Oats	60	II	25	50
Maize	81			
Wheat bran	43			
Gram husk	35	III	..	40
Cotton seed husk	10			
Rice husk	8			
Barley	71	IV	..	25
Wheat	72			

FEEDING FOR ANTICIPATED YIELD.

Farmers should feed an increased concentrate ration to animals in the milking herd in anticipation of yields in the following cases:

(*a*) When the herd shows a sudden falling off in milk due to a spell of bad weather, the previous week's milk yield may be allowed to stand, so as to give the herd an extra concentrate ration in anticipation of their recovery.

(b) When an animal calves, it may be fed extra concentrate ration in anticipation of what it is going to give. For example, if it is anticipated that a cow will give 30 lbs. a day, it may be fed as if it was actually giving this amount. If it reaches 30, it may be fed for 40 and so on.

This is subject to the following restrictions:—

i. The anticipatory concentrate ration should not be continued beyond a month from calving.

ii. The anticipatory concentrate ration should not be for more than 10 lbs. of milk above what the animal is actually giving.

iii. If the animal shows no increase in two weeks, or the increase is only slight, the anticipatory concentrate ration should be stopped and animal fed according to its actual yield.

NOTE. Whenever an animal is fed an anticipatory concentrate ration, the anticipated yield can be written in the form (Appendix II) in red ink over the actual yield in black ink. In the case of whole herd being fed extra concentrate rations, the same procedure can be followed. The above does not include an animal having a drop in yield due to an illness. Such cases are provided for under column 5 of the above form.

EXPLANATION OF LETTERS AND NUMBERS EMBODIED IN THE TABLES.

(a) All numbers unless otherwise stated denote pounds.

(b) In Table A no change in the concentrate mixture scale is made for fodder fed.

(c) In the case of Tables B, C and D the quantity of concentrate mixture allowed will depend on the fodder fed as under:—

(1) Concentrate mixture under Scale A should be given when all the fodder fed is dry; such as *bhoosa*, *kirbi*, dry grass, etc.

Important. It is never advisable, if it can possibly be avoided, to feed, especially to cows, only dry fodder.

(2) Concentrate mixture under Scale B should be given when approximately 75 per cent. of the fodder is dry and 25 per cent. green or 100 per cent. early cut and well cured hay.

(3) Concentrate mixture under Scale C should be given when approximately 50 per cent. dry and 50 per cent. green fodder is fed.

(4) Concentrate mixture under Scale D should be given when 75 per cent. or over of green fodder is fed with 25 per cent. or less of dry fodder.

Important. It is never advisable to feed 100 per cent. green fodder to cattle especially if the fodder contains excessive moisture.

NOTE 1. Roots and silage count as green fodder.

NOTE 2. When green fodder with an excessive moisture contents is fed, *e.g.*, berseem, roots, etc. 33⅓ per cent. extra to what is allowed under the green fodder category should be given.

Note 3. In cases when a mixture of dry and green fodder is fed not exactly in the above proportions, the farmer should feed in the nearest category using his own judgment.

Note 4. Green fodder cut too dry to be classified under green should be classified for quantity to feed in categories c (2) and c (3) according to its moisture contents and the concentrate mixture fed accordingly. Semi dry fodders containing an appreciable quantity of grain should be classified for quantity to be fed as above but the concentrate mixture should be fed as per Scale D.

Note 5. If fodder is not chaffed or cut up, 20 per cent. extra should be fed.

Note 6. When grazing is available, it should be classified into c (2), c (3) or c (4) according to its moisture contents and the quantity of fodder fed decreased as follows :—

(a) When grazing is fair	25 per cent.
(b) When grazing is good	50 „
(c) When grazing is excellent	75—100 „

Animals on permanent closely grazed yet abundant and green nutritious pastures should be fed on concentrate mixture Scale D less 50 per cent.

It is difficult to overestimate the advantage of natural permanent nutritious pastures for economic milk production.

Examples.

A farmer has, amongst others, the following animals in his herd :

1. A cow weighing 700 lbs. and giving 15 lbs. of milk daily.
2. A cow weighing 850 lbs. and giving 22 lbs. of milk daily.
3. A buffalo weighing 1,100 lbs. and giving 29 lbs. of milk daily.
4. A buffalo weighing 1,210 lbs. and giving 23 lbs. of milk daily.
5. A calf weighing 80 lbs., 14 days old.
6. A buffalo weighing 1,100 lbs., to calve in 1 month.
7. A cow bull weighing 950 lbs.. in service.

He intends feeding as fodder 50 per cent. *bhoosa* and 50 per cent. chaffed green *jowar.*

What quantity of concentrate mixture (Standard), *bhoosa* and green *jowar* should each animal receive ? The mean temperature in the cattle sheds during the week was 75° F. The condition of all animals is good.

From " Explanation of letters and numbers embodied in the Tables " c (3), the concentrate mixture should be fed under Scale C.

From Table B :—

Cow No. 1 would receive 6 lbs. concentrate mixture, 7 lbs. *bhoosa* and 35 lbs. green *jowar.*

Cow No. 2 would receive 9 lbs. concentrate mixture, 7 lbs. *bhoosa* and 35 lbs. green *jowar.*

Buffalo No. 3 would receive 10 lbs. concentrate mixture, 11 lbs. *bhoosa* and 55 lbs. green *jowar*.

Buffalo No. 4 would receive 9 lbs. concentrate mixture, 12 lbs. *bhoosa* and 58 lbs. green *jowar*.

NOTE. Cow No. 2 and Buffaloes Nos. 3 and 4 get extra rations for weight. Fodders are worked out to the nearest pound.

From Table A :—

Calf No. 5 would receive 12 lbs. of milk a day.

From Table C :-

Buffalo No. 6 would receive 6 lbs. concentrate mixture, 11 lbs. *bhoosa*, and 55 lbs. green *jowar*.

NOTE. An extra 2 lbs. of concentrate mixture is given for being near calving.

Cow bull No. 7 would receive 4 lbs. concentrate mixture, 7 lbs. *bhoosa* and 35 lbs. green *jowar*.

RATION TABLE A.

For calves up to 9 months.

Ration to be fed for every 10 lbs. body weight.

Age	Dam's colostrum lbs.	Milk lbs.	Separated Milk lbs.	Concentrate mixture lbs.	FODDER Quantity to be fed: If all dry lb.	FODDER Quantity to be fed: If all green lb.	No. of times to be fed daily.
1st day	1	..	...	...	...	...	4
2nd to 3rd day	1½	..	...	...	...	...	4
4th to 6th day	..	1½	...	...	...	...	3
1st to 3rd week	..	1½	...	...	..	...	2
4th to 6th week	..	1	...	1/20	1/6	¾	2
6th to 9th week	..	¾	½	1/16	1/6	¾	2
10th week	..	¼	1	1/14	1/6	¾	2
11th to 15th week	...	..	1	1/12	1/5	1	2
16th to 17th week	..	..	¾	1/10	¼	1¼	2
18th to 19th week	..	..	½	1/8	¼	1¼	2
20th to 21st week	..	..	¼	1/8	¼	1¼	2
22nd to 38th week	..	..	...	1/10	¼	1¼	2

NOTE 1. Rations should be worked out to the nearest pound in the case of colostrum, milk, separated milk and fodder, and to the ½ pound in the case of concentrates.

NOTE 2. If a calf does not gain approximately 7 lbs. a week up to 4 months old, it should receive individual attention.

Ration Table B.

For the milking herd weighing up to 800 lbs.

Daily milk yield lbs.	Concentrate Mixture				Fodder Quantity to be fed	
	A	B	C	D	If all dry	If all green
1–3	5	3	2	...	14	70
3–6	6	4	2	1	14	70
6–9	7	5	3	1	14	70
9–12	8	6	4	2	14	70
12–15	9	7	5	3	14	70
15–18	10	8	6	4	14	70
18–21	11	9	7	5	14	70
21–24	12	10	8	6	14	70
24–27	13	11	9	7	14	70
27–30	14	12	10	8	14	70
30–33	15	13	11	9	14	70
33–36	16	14	12	10	14	70
36–39	17	15	13	11	14	70
39–42	18	16	14	12	13	65
42–45	19	17	15	13	13	65
45–48	20	18	16	14	12	60
48–51	21	19	17	15	12	60
51–54	22	20	18	16	11	55
54–57	23	21	19	17	11	55
57–60	24	22	20	18	10	50
60–63	25	23	21	19	10	50

Extra ration to be fed for weight.

Weight in lbs.	ADD THE FOLLOWING											
	Buffaloes						Cows					
	Concentrate mixture				Fodder		Concentrate mixture				Fodder	
	A	B	C	D	If all dry	If all green	A	B	C	D	If all dry	If all green
800—1,000	2	1	...	..	7	35	2	2	1	1	...	...
1,000—1,200	2	1	...	...	8	40	3	3	2	1	..	...
1,200—1,400	3	2	1	1	9	45	4	4	3	2	2	10
Over 1,400	4	3	2	2	10	50	6	5	4	3	3	15

NOTE 1. To facilitate feeding extra fodder to heavier animals, animals should be grouped in the cattle shed according to their weights and fodder weighed out for certain groups and not individual animals.

NOTE 2. The extra ration to be fed to buffaloes for weight also includes a "fat in milk" allowance.

NOTE 3. The extra allowance for cows for weight will practically only affect animals with imported blood. Such animals require a higher nutritive ration than either country cows or buffaloes.

NOTE 4. As all animals should be dried off two months before calving, an extra ration scale for pregnancy is not necessary under this Table. See Table C.

RATION TABLE C.

For (*a*) Animals over 9 months old but not in adult herd.

(*b*) Adult females not in milk.

1. Cows.

Weight in lbs.	CONCENTRATE MIXTURE				FODDER	
					QUANTITY TO BE FED	
	A	B	C	D	If all dry	If all green
Under 400	4	3	3	2	6	30
400—600	6	4	4	2	8	40
600—800	8	5	4	3	10	50
800—1,000 . .	9	6	5	3	11	60
1,000—1,200	10	7	5	3	15	75
1,200—1,400 . .	11	8	6	4	16	80
Over 1,400	12	9	6	4	17	85

2. *Buffaloes.*

Weight in lbs.	Concentrate Mixture				Fodder: Quantity to be fed	
	A	B	C	D	If all dry	If all green
Under 400	3	2	2	1	12	60
400—600	4	3	3	2	14	70
600—800	5	4	3	2	16	80
800—1,000	6	4	3	3	18	90
1,000—1,400	7	5	4	3	22	110
Over 1,400	8	6	4	3	24	120

Extra concentrate mixture to be fed to animals in calf.

To calve in	A	B	C	D
3 months	2	2	1	1
2 months	3	2	2	2
1 month	3	3	2	2

NOTE 1. Animals should be grouped according to their weight for feeding the fodder ration.

NOTE 2. Every animal should be tied up separately to receive their concentrate mixture. This handling not only ensures that each animal actually consumes its correct ration but greatly facilitates the subsequent handling in the milking shed.

RATION TABLE D.

1. *For adult cow bulls.*

Weight in lbs.	Concentrate Mixture				Fodder: Quantity to be fed	
	A	B	C	D	If all dry	If all green
Under 1,000	7	5	4	3	14	70
1,000—1,200	9	7	6	5	14	70
1,200—1,400	11	9	8	7	16	80
Over 1,400	13	11	10	9	18	90

2. *For adult buffalo bulls.*

Weight in lbs.	Concentrate Mixture				FODDER Quantity to be fed	
	A	B	C	D	If all dry	If all green
Under 1,000	6	4	3	2	18	90
1,000—1,200	8	5	4	3	20	100
1,200—1,400	9	7	6	5	22	110
Over 1,400	11	9	8	7	24	120

Note 1. If a bull is idle, the concentrate mixture should be reduced by 33⅓ per cent.

Table E.

The farmer should feed extra ration to his cattle during the winter months as follows :—

If the mean temperature of the week inside the cattle-shed is above	70° F	*Nil.*
If the mean temperature of the week inside the cattle-shed is between	60°—70° F	1 lb. of concentrate mixture.
If the mean temperature of the week inside the cattle-shed is between	50°—60° F	2 lbs. ditto
If the mean temperature of the week inside the cattle-shed is between	40°—50° F	3 lbs. ditto
If the mean temperature of the week inside the cattle-shed is between	30°—40° F	4 lbs. ditto

Note 1. The above extra ration should only be fed to adult animals.

Note 2. To obtain accurate figures as to the actual temperature effecting the animals, the farmer should hang a maximum and minimum thermometer in the cattle shed. If he has several sheds varying greatly in construction with resulting variations in daily temperatures, he should hang a thermometer in each shed.

Note 3. The scale of extra ration to be fed for temperature given above is based on temperatures prevailing inside the cattleshed, where the cattle are housed during the major and coldest portion of the 24 hours. This will be higher in the winter and lower in the summer than the temperatures shown in the official meteorological reports.

Note 4. It has been assumed that when the mean temperature inside the shed falls below 60° F animals will be bedded down, and when it falls below 50° F each animal will be jhooled up during the night.

Note 5. The farmer should be careful to see that whilst his animals get ample fresh air they are not exposed to draughts, and do not have to lie on wet standings, sodden bedding, etc.. as no amount of food will make up for actual discomfort.

Note 6. As a rule it is sufficient to make additions to the ration for temperature once a week. In the case of a sudden marked drop in temperature the farmer may find it advisable to increase his ration immediately.

Note 7. The mean temperature of the week can be calculated by adding together the daily mean temperature of that week and dividing by 7. The daily mean temperature is arrived at by adding together the minimum and maximum temperature of the day and dividing by two. The minimum and maximum temperature should be taken daily by the person-in-charge of the cattleyard at 10 A.M. and recorded in the temperature record book.

TABLE F.

Mineral feeding.

Generally speaking, the danger of mineral deficiency in the dairy animals ration in India is ever present. Although little experimental work has been done on this subject, it appears that this danger is dependent to some extent on the following factors :—

(1) The milking capacity of the herd. It is considered advisable to feed a mineral ration to any herd with a lactation average of over 5,500 lbs.

(2) The percentage of dry non-leguminous fodder fed throughout the year. Mineral shortage is very likely to manifest itself in those herds receiving little or no green fodder, especially if the concentrate mixture also has a low mineral content.

(3) The percentage of imported blood in the animals. It seems that animals with imported blood require a higher standard of available (or more easily available) minerals in their food.

(4) The locality. A little data has been collected on this point, but it cannot be discussed in this paper.

Mineral deficiency is often indicated by malnutrition, contagious abortion (?), the birth weight of calves or milk yields. The last is not very informative, unless studied in conjunction with a large amount of accurate experimental data.

As a guide, if the weight of calves born are consistently below the following formula, then deficiency of minerals should be one of the factors suspected.

$$\frac{(\text{Weight of Dam})\times 2+\text{weight of bull}}{60}=\text{Weight of female calf at birth.}$$

Male calves usually weigh about 20 per cent. more.

If mineral deficiency is suspected, minerals should be fed daily to animals over 9 months old in the following proportions :—

(*a*) Animals 9 months to 2½ years	2 oz. of mixture.
(*b*) Animals over 2½ years	4 oz. of mixture.

The mineral mixture should consist of :—

Steamed bone meal	40 lbs.
Ground limestone	20 lbs.
Common salt	20 lbs.

The mineral mixture should be measured out for each animal and well mixed with the concentrates. The quantity allowed being divided up according to the number of concentrate feeds an animal receives.

Table G.

Salt.

Each adult animal should receive approximately one ounce of salt per diem.

This may be given :—

(*a*) As rock salt hung up so that an animal can lick it whenever desired.

(*b*) As fine salt in the grain mixture.

The former is preferable.

When a mineral mixture is fed, there is no need to feed an extra quantity of salt. Rock salt may, however, continue to be hung up.

Table H.

Water.

The importance of water is often forgotten by farmers. Unless the milking herd can get their full requirements, the yields, despite any feeding, are bound to suffer. Water should be provided in every paddock frequented by the herd. If this cannot be done, they should be given plenty of time at the watering place to satisfy their thirst at least four times a day.

In the hot weather the need for water is, of course, even greater.

When the mean temperature of the week drops below 40°F. the drinking water should be warmed.

Automatic watering bowls in the sheds are convenient and appreciated by the animals but not a necessity.

Appendix I.

The form given overleaf has been drawn up to facilitate rationing the milk, separated milk, and concentrates fed to calves as per Table 'A'.

Note 1. If a calf is not making satisfactory progress, a slightly increased ration than that laid down in Table 'A' may be given. The extra ration should be written in red ink after the standard ration and connected with it by a *plus* sign. As a guide, up to the age of four months, the weight on birth in pounds *plus* age in days should not be less than the present weight in pounds.

Note 2. The total milk, separated milk and concentrates issued for the day should connect up with the other accounts maintained on the farm.

Note 3. Calves born after the commencement of the ration statement week can be entered thereon.

Note 4. For convenience, all calves, irrespective of age, should be weighed on the day the ration statement week commences. The present weight indicates weight on that day.

Note 5. Colostrum from the dam should be fed to the calf for the first four days. This should be shown as milk on the ration statement.

Ration Statement I for calves from birth to nine months for week ending..................

Date.																	Total.	Initial of the person incharge of calves.	Initial of the Manager of the Farm.
	Number																		
	Name																		
	Weight on birth																		
	Age in days																		
	Present weight																		
	Condition — Good																		
	Condition — Fair																		
	Condition — Bad																		
	Milk																		
	Sep. Milk																		
	Concentrates																		
	Milk																		
	Sep. Milk																		
	Concentrates																		
	Milk																		
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	Concentrates																		
	Milk																		
	Sep. Milk																		
	Concentrates																		

APPENDIX II.

The form overleaf has been drawn up to facilitate the rationing of concentrates to adult milking stock, dry stock, bulls and young stock over 9 months.

NOTE 1. It is advisabie to use a separato form for different classes of animals.

NOTE 2. In column 6 'milking average for the week' of course only applies to animals in milk. By 'service' is meant whether bulls are in service or idle. These animals should be marked I for idle and S for service and fed accordingly, see note to Table D.

NOTE 3. In column 7 'month to calve' only applies to adult female not in milk (Table C).

NOTE 4. The condition of the animal should be noted in column 5 by using the appropriate letter.

If the animal is too fat, the ration should be reduced and if its condition is bad, the ration should be increased. See column 10.

Ration Statement II for milking stock, dry stock, bulls and young stock over nine months for the week ending..............

....

1	2	3	4	5	6	7	8	9	10	11	12	13
Number of animal	Name of animal	Ration scale being fed as per Table	Weight	Physical condition F—Fat G—Good M—Medium B—Bad	Milking average for the week	Months to Calve	Concentrate Mixture allowed under 3 and 6	Mixture allowed under			Extra mixture allowed for temperature Table G	Total of columns 8, 9, 10, 11 and 12
					Service			4	5 *Plus* or *minus*	7		
			lbs.				lb.	lb.	lb.	lb.	lb.	lb.
											Total .	

APPENDIX III.

The form given below has been drawn up to facilitate the serving and drying off of animals at the proper time and estimating with reasonable accuracy the calving date. It is necessary to have the latter information to utilise Table "C" correctly.

NOTE 1. Names of animals should be entered on this statement as they calve.

NOTE 2. The date an animal should be served after calving depends on a large number of factors which cannot be discussed in this paper.

NOTE 3. The date of service should be written in pencil until it is definitely known that the animal has held to that service.

NOTE 4. The date of drying off will depend on several factors but as a rule should be 60 days before the animal is due to calve. First calvers should not be kept in milk over 365 days.

NOTE 5. The date due to calve will be approximately date of service *plus* 282 days for cows and date of service *plus* 306 days for buffaloes.

NOTE 6. The actual date calved should be recorded in the statement to facilitate checking the correctness of service recorded.

NOTE 7. From this record the actual number of animals to calve in future months can be easily tabulated.

Service and calving statement.

No. of animal	Name of animal	Date calved	Date due for service	Date served	Name of bull	Date due to be dried off	Date due to calve	Date calved

EQUINE MICROFILARIASIS: A SHORT REVIEW OF THE LITERATURE.*

BY

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Of late, inquiries have been addressed to this Institute concerning any known remedy suitable for application under field conditions in the treatment of microfilariasis of the horse, and before the Institute felt itself in a position to advise the correspondents concerned, the present writer was asked to prepare a résumé of available literature on the subject, not only setting forth therein the main lines hitherto evolved in the treatment of the disease, but also indicating, in the first place, the extent to which the disease has been regarded by various workers as a morbid entity of any importance as affecting the health of the equine species. In what follows, it is proposed to discuss, as briefly as possible, certain points of interest that emerged in the course of an analysis of the findings recorded by the different workers.

THE SPECIES OF MICROFILARIÆ RECORDED FROM THE BLOOD OF EQUINES.

A perusal of the available literature shows that only two species of microfilariæ have been definitely recorded from the circulating blood of equines, namely, *Setaria equina*, Abildgaard, 1789 (=*Filaria papillosa*, Rudolphi, 1802) and *Filaria spirovoluta*, Smit and Ihle, 1925[1]. Curiously, the young forms of *Parafilaria multipapillosa*, Condamine and Drouilly, 1876 (=*F. hæmorrhagica*, Raillict, 1885) do not appear to have been observed in the circulating blood of equines, although, as is well known, the adult filariæ of this species are of not infrequent occurrence in the subcutaneous connective tissue of the horse. Neveu-Lemaire [1912] and Hutyra and Marek [1926], in their recent edition of *Special Pathology and*

* Paper read at the Medical and Veterinary Research Section of the Indian Science Congress, Allahabad, January 1930.

[1] The identity of what is designated as *S. labiato-papillosa* (the immature forms of which occur in the eye of the horse) would appear to be disputed, and certain authors (*e. g.*, Underhill, 1924) evidently regard *S. labiato-papillosa* as identical with *S. equina*.

Yakimoff and his co-workers (1915) recovered what they called *Microfilaria ninae kohl-yakimoffi* from the blood of horses in Turkestan, but the identity of these is not clear.

Therapeutics state that the evolution of this parasite is unknown. Likewise, Railliet's original description of this parasite, as published in *Traite de Zoologie* [1895], does not contain any reference to the embryos of *P. multipapillosa* occurring in the blood, although both Neveu -Lemaire and Railliet observe that the liberated embryos measure 220 -230 microns in length. As emphasized by Foley and his collaborators [1928], however, the study of filarial embryos is fraught with difficulty, and it must not be assumed that only one species is present until the embryos occurring in the blood have been carefully compared with those in the terminal part of the uterus of the adult female, if the latter has been found. It is thus not improbable that, from a careful study on the lines recommended by Foley and his co-workers, it may transpire that in a certain proportion of the cases, the filarial embryos designated as *S. equi* are in reality *P. multipapillosa*.

Relative Incidence of Microfilariasis amongst Equines and other Species of Animals.

Compared with the dog, the equine species would appear to be little susceptible to filarial infection, and during recent years, cases of canine microfilariasis have come to the notice of this Institute on fairly frequent occasions. As an extreme instance of the widespread occurrence of the disease may be cited the observations published by Bodkin and Cleare [1916], according to which "it would probably be a difficult matter to find [in British Guiana] a creole dog over two years of age which does not harbour this parasite". On the other hand, the rarity with which the parasites have been found to occur in the blood of equines is illustrated by the fact that a systematic examination of 19,000 blood smears in a certain Remount Depot in India resulted in the parasites being "found once only in six mules and five horses". Information is not available concerning the incidence of equine microfilariasis in other countries, except in Turkestan, where, according to Yakimoff and his collaborators [1915], the rate of incidence of the disease varies within wide limits—from 0·53 to 37·6 per cent., whilst in the case of the donkey, they found 19 animals to be affected out of 847 examined by them[1]. The figures obtainable for camels are from 4 to 22·5 per cent. in four different districts in Turkestan (Yakimoff and his collaborators, 1914), whilst, in a recent paper, Zeiss [1927] gives 0·25 to 0·5 only as the percentage of camels infected in South-Eastern Russia. In regard to the incidence of the disease in the Indian Region, Leese [1908] reported that out

[1] It is of interest in this connection that Yakimoff and his collaborators (1917), in Russian Turkestan, found microfilariæ to be entirely absent in the circulating blood of sheep, although they examined as many as 1844 of these animals for evidence of this infection.

of 1,500 camels examined by him in various camel corps in India, only two cases showed filarial infection, although, according to Cross [1922-1923], "the disease is common in camels".

Clinical Symptoms of Microfilariasis in Equines.

In a great majority of the cases of equine microfilariasis recorded by various workers, no definite clinical symptoms have been reported, and in a few instances where this has been done, the symptoms were not such as could not be ascribed to causes other than microfilariasis. As a matter of fact, several workers have noted the occurrence of microfilariasis in the horse as a condition concomitant with other forms of blood infection, where systematic examination of blood smears has been resorted to as a routine procedure, so that the possibility suggests itself that a more extensive search would result in the finding that a proportion of the equine species normally harbour these parasites without developing any visible clinical symptoms. The more notable observations on record upon the nature and extent of morbid disturbances evoked in the equine species by the presence of these parasites may be summarized as follows.

(a) *Occurrence of Microfilariasis in Conjunction with other Diseases.*

Macalister [1917], in India, in the course of a lengthy discussion upon the ætiology of "Kumri" refers to the frequent association of this disease with *Setaria equina*, and this would appear to lend considerable *primâ facie* support to the view that the two are ætiologically connected. He concludes, however, that "this is to be regarded as a chance conjunction and not implying a causal relationship".

Aldigé [1920], in French West Africa, observed that the occurrence of filarial embryos was frequently associated with trypanosomiasis (*Trypanosoma congolense* infection), especially in New Guinea and Senegal, and also with such other local diseases as might be prevailing at the time, and in certain instances the parasites were even detected by him in the blood of healthy animals, although their presence was not revealed by any manifest symptoms.

In regard to the so-called "Fez" disease (infectious anæmia) of the horse in Morocco, it was demonstrated by Velu [1921] that this disease did not represent a single entity but that it comprised as many as four infections, namely, trypanosomiasis, spirillosis, piroplasmosis, and microfilariasis.

The occurrence of microfilariæ in the blood of equines affected with trypanosomiasis has been mentioned by a number of workers, and the presence of the parasites has not infrequently been detected at this Institute in the course of the

routine examination of blood smears from animals experimentally infected with surra trypanosomes. Likewise, in the case of the Remount Depot mentioned earlier in this paper, the parasites were found in smears taken from mules and horses belonging to a " surra area ". Similar remarks apply also to the bovine species, for Teague and Clark [1918] readily demonstrated the presence of filarial embryos in the blood of Panama cattle affected with trypanosomiasis, and Ford [1919], in the Malay States, found them in the blood of an Indian bull suffering from surra, whilst, recently, Davis [1929], in the Sudan, has described the occurrence of filarial embryos in the blood of a bull suspected of trypanosomiasis. The two infections have also been sometimes found coincident in the camel, as is illustrated by an instance cited by Littlewood [1919-20], in Egypt, whilst, in India, " surra and filariasis are often found in the same animal " and " this has generally complicated the investigation of the latter disease " [Leese, 1910].

(b) *Clinical Symptoms definitely ascribed to Microfilariasis.*

From the descriptions given by various workers of the symptoms of the disease, one finds it difficult to resist the impression that microfilariasis of the horse is not associated with any clear clinical picture. Symptoms have been described which are characteristic of diseases referable to widely different categories (*e.g.*, trypanosomiasis, glanders), or, else, except for the occurrence of eosinophilia (indicative of general verminous infections), the symptoms described are so diffuse (*e.g.*, "debility", " wastage ", " anæmia ", etc.) as to be applicable to a number of other affections. The truth of this statement is illustrated by the following citations.

Littlewood [1914], in Egypt, found that the occurrence of filarial embryos in the circulating blood of equines was characterized by the presence of petechiæ, anæmia and wasting. Wirth [1917], in Hungary, observed that microfilariasis of the horse was associated with " general lassitude ", " somewhat diminished appetite " and the heart action being " violent on slight exertion ", although the parasites were sometimes detected by him in the blood of horses showing no apparent symptoms of disease.

Yakimoff and his collaborators [1915], in Turkestan, found the disease to be characterized by the presence of abrasions (due to irritation), œdematous swellings (sometimes) and rapid exhaustion. These authors also refer to the occurrence of albuminuria as observed by Mandel [1910], although they themselves were unable to confirm this observation.

Ford [1919], working in the West Indies and the Malay States, cites the remarkable instance of an Australian race horse, in which the presence of filarial embryos was associated with the development of clinical symptoms of glanders.

According to Vleming [1917], the acute form of equine filariasis in Surinam is characterized by such general symptoms as wasting, anæmia, and œdematous swellings, whilst the microfilariæ are said to resemble the involution forms of trypanosomes, with the appearance of anaplasma -like bodies in the erythrocytes [1].

Aldigé [1920], in French West Africa, refers to the similarity of the symptoms of equine microfilariasis to those of trypansomiasis, with this difference that the former were of "slower development" without any marked febrile crises or paresis of the hindquarters, but the affected animals developed petechiæ on the conjunctiva and œdematous swellings on the dependent parts, with other forms of dermatitis and pustular eruptions. It is of interest that the swellings and eruptions were seen by him not only in horses infested with microfilariæ, but also on others infected simultaneously with *Trypanosoma dimorphon*, or with *T. dimorphon* alone, although in the conditions of the last category, the swellings were "less persistent, more doughy and less hot and painful" than those due to microfilariasis.

Beal [1920], in the Gold Coast, regards microfilariasis in horses to be the cause of an intermittent fever "associated with other symptoms," whilst Blanck [1927], in the Sudan, noticed marked evidence of wasting and general signs of anæmia in a horse infested with these parasites, and the condition of the animal appeared to him to be one of oligæmia.

In the case of the affected horses in the Remount Depot in India mentioned above, the presence of the parasites did not give rise to any notable symptoms, beyond a slight elevation of temperature, although the parasites were sometimes persistently present in the circulation, being detected twice in one horse, five times in another, and as many as eleven times in a third.

It is of interest that the observations on record in regard to the clinical symptoms of microfilariasis in other animals are no less divergent. Thus, while Teague and Clark [1918] found filarial embryos generally innocuous for Panama cattle, Oguni [1927] causally connected them with a form of scabies (so-called "wahi" or "kose") in Japanese cattle. In the camel, Mason [1911], in Egypt, found the symptoms of microfilariasis to resemble those of trypanosomiasis, whilst Leese [1910] and Cross [1922-23], both in India, mention "loss of condition" and "a considerable rise of temperature" (when the parasites are present in the peripheral circulation) as notable symptoms of the disease. In the dog, likewise, microfilariasis has been variously characterized from being "very fatal" [Richardson, 1925, in Uganda] to being devoid of noteworthy symptoms [Foley, 1921, in Algeria].

[1] As remarked by a reviewer of Vleming's paper, one strongly suspects that the author was here dealing with an outbreak of surra.

It would thus appear from the foregoing extracts that the observations recorded by various workers, in regard to the nature and extent of morbid disturbances evoked by the occurrence of filarial embryos in the circulating blood of the different species of animals, afford one reasonable ground for thinking that the clinical symptoms that have been attributed to a microfilarial invasion in these animals may (at any rate, in a large proportion of the recorded cases) have been, in reality, due to causes other than microfilariasis [1].

Treatment of Equine Microfilariasis.

As one would expect, in the absence of precise knowledge as to the pathogenic rôle played by filarial embryos, the various forms of therapeutic treatment designed to combat these parasites have been of a very empirical character. So far as the equine species is concerned, Wirth [1917] found that no special treatment was called for, as the disease generally ran a favourable course, although recovery did not take place before two to four months from the onset of the disease. Wirth, however. tested the efficacy of atoxyl, without any beneficial results. Yakimoff and his collaborators [1915] found the intravenous injection of salvarsan valueless. Aldigé [1920] would appear to have given a fairly extensive trial to the various products utilized in the treatment of trypanosomiasis, namely, orpiment, atoxyl, trypanblue, trypanred, and tartar emetic, but except for the last, all the drugs tested by him yielded negative results. With tartar emetic, the injection of the drug in from 1·2 to 1·4 gramme doses was followed by the disappearance of the parasites and an amelioration of the symptoms, provided the injections were repeated from four to twelve times (one or two injections were found by him to be valueless). In the case of the affected horses in the Remount Depot mentioned above, treatment was attempted by the intravenous administration of single doses (50 c. c. of a 10 per cent. solution) of "Bayer 205", but the results were negative.

As a matter of fact, only a limited number of drugs would appear to have been tested as to their efficacy for animal microfilariasis. Of these, mention may be made of galyl, which was employed by Curasson [1920], in doses of 0·5 c. c. of a 1 per cent. solution per kilo., intravenously, in the treatment of microfilariasis of the carrion crow, but the application of this remedy resulted only in a partial recovery. For the treatment of the microfilariasis of the dog (due to *Mf. immitis*), Itagaki and his collaborators [1927], in Japan, employed sodium antimonyl tartrate, administered intravenously in doses ranging from 0·003 to 0·004 gramme per kilo. body weight, at intervals of one or more days. The treatment is claimed by them to have resulted in a disappearance of the embryos from the circulation of the affected animals.

[1] A view which would seem warranted even allowing for the possibility that the parasites concerned in the cases described by the serveral authors were not specifically identical.

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SELECTED ARTICLE

INTERIM REPORT ON THE IMMUNISATION OF DRAFT ANIMALS IN BURMA AGAINST ANTHRAX.

BY

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DISTRIBUTION.

The distribution of anthrax in this Province is widespread. In the last two years, during which time an effort has been made to increase the number of blood smears submitted for microscopic examination from dead animals in the districts, the disease has been recorded from practically every district.

It usually occurs in sporadic form and results in the death of only a few animals in each outbreak, so there is every reason to presume that many of these outbreaks in cattle and buffaloes pass unnoticed. Epidemics have been recorded in wild animals in the neighbourhood of an outbreak in domestic stock, and as practically all species, with the exception of carnivora, are highly susceptible, such an epidemic seriously complicates the ordinary preventive measures of segregation or isolation.

Where animals are concentrated in any area, the disease is liable to assume epidemic form. As examples of this, we have the recent mortality (1928-29) in the horses of the Rangoon Paper Chase Club and the annual epidemics which have occurred up to the present in the elephants of the timber firms, working in infected forest areas.

MORTALITY FROM ANTHRAX.

It is very difficult to arrive at any estimate of the losses which are occurring in cattle and buffaloes from this disease as it can only be definitely diagnosed by microscopic examination of blood smears. The difficulties at present existing in getting smears from animals which die in the village-tracts are almost insuperable and

many years will require to elapse before the villager can be taught to realise the importance of a correct and early diagnosis in the prevention of epidemic disease in stock. The grouping of black quarter, hæmorrhagic septicæmia and anthrax under one heading in the annual report of the Department indicates the present position regarding diagnosis. So long as the returns submitted by the Thugyi remain the principal source of information in compiling mortality statistics, little reliance can be placed on these as an index of distribution of disease or mortality in animals.

In the case of elephants the methods of recording mortality and submitting material for a laboratory diagnosis are well organised by the firms concerned, and the records can be relied upon. The mortality from anthrax in these returns over a period of years is a staggering figure when converted into terms of cash. One reads of losses from anthrax varying from 20 to 90 animals per annum in the herds of one of the firms concerned.

ECONOMIC VALUE.

The average total annual mortality from anthrax in working elephants in Burma has not yet been worked out, but it may be taken for the purpose of illustration at the low estimate of 60 animals. The average value of these animals is about Rs. 5,000 each or Rs. 3,00,000. Averaging the season's work of one elephant at 80 tons of timber, the royalties to the Government in respect to 60 elephants works out at about Rs. 1,16,160 which are indefinitely or permanently deferred.

To this must also be added the loss in holding up the work in a forest where an outbreak occurs and the loss of profit on the timber which might have been extracted, etc., which cannot be estimated.

These figures in relation to *one class of animal and one section of Agriculture only* gave one some idea of the economic importance of the problem and indicated that research into methods of prevention should be considered first among the very urgent problems which confronted the Veterinary Department in Burma.

RESEARCH WORK BEGUN.

A Special Research Officer was appointed in December 1927, but it was not found possible to commence serious work on anthrax until nearly a year later, October 1928. This was due to (*a*) the necessity for training a staff in general laboratory duties, (*b*) the provision of internal fittings for the laboratory, (*c*) the absence of suitable apparatus and equipment which had to be purchased locally, borrowed or ordered from England, (*d*) repairs to Incinerator, (*e*) arrangements for the supply of small laboratory animals, etc., etc.

Considerable difficulty was experienced in procuring a local strain of anthrax from each species. Specimen bottles for despatch of a piece of dried ear from suspected cases were distributed. but the fear of spreading infection prevented specimens being freely submitted. Only one specimen from an elephant was found to be infective, although smears from animals, dead of the disease, were frequently being received.

STRAINS USED.

This specimen came from an elephant of Messrs. T. D. Findlay of Nyaunglebin on 8th March 1928 and the strain was used in these tests as the virulent anthrax emulsion. Strains from cattle and horses were secured from local outbreaks in the Insein area.

For the production of the vaccine a strain was used which was brought from South Africa in 1927 and was of "Bovine" origin. This was obtained with other anthrax strains, through the courtesy of the Director of Veterinary Services, Union of South Africa.

NATURE OF VACCINE.

The preparation of the vaccine was carried out on lines similar to those employed in South Africa and recorded in the Annual Report of the Department Union of South Africa. The finished vaccine consists of a suspension of living anthrax spores, freed from the bacilli, from a strain attenuated to a fixed degree by incubation at a temperature higher than the optimium, in a solution of water and glycerine. It is therefore a very stable product and one which, even in jungle conditions in Burma, may be expected to remain unchanged for a considerable period if given a reasonable amount of protection from light and heat.

NATURE OF THE VIRULENT ANTHRAX MATERIAL.

The virulent anthrax suspension was prepared by isolating the strain from the case in the elephant at Nyaunglebin and growing it under ordinary incubator conditions in the laboratory. The virulent suspension was prepared by emulsifying the spores in old cultures in water and glycerine. For use, this emulsion was standardised on sheep. The minimum amount required to kill a sheep being named in this report "The M. L. D." which was found to be 0·00005 c.c.

The virulency of this strain was found to be about double that of a virulent cattle strain which has been brought from South Africa.

The dose of the vaccine was calculated on the amount required to protect a sheep one month later against 1,000 M.L.D. of virulent spore emulsion by an experiment on a series of these animals.

Having thus produced a supply of standardised attenuated anthrax spore emulsion for use as a vaccine and a standardised virulent anthrax spore emulsion of elephant strain for use as a test of the immunity produced, it was possible to consider arrangements for estimating the value of the vaccine prepared from the South Africa strain against the local Burmese strains of anthrax. The strains in the various species of animals in Burma do not show very much variation and the history of outbreaks indicate that in all probability the strains present in elephants, cattle and buffaloes are the same or may be considered so at present from the point of view of immunisation.

Tests on Sheep.

Preliminary laboratory test on sheep were commenced on 5th January 1929. Batch (1) anthrax vaccine was used and varying doses were given from 0·1 c.c. to 20·0 c.c.

The results from this batch of sheep were unsatisfactory. The animals were allowed to graze in the Research Laboratory compound and a very heavy mortality occurred a few days after inoculation from a condition resembling plant poisoning. None of the animals showed anthrax on blood examination. It was later established by animal experiment that this condition was due to eating the thorny branches of the "sensitive plant" (Mimosapudica) which was very plentiful and at an attractive stage. The sheep had come from the dry zone and were not accustomed to the local Insein vegetation.

The test was repeated on 18th February 1929 on a further batch of sheep which, on this occasion, were stable throughout the tests.

Vaccine in doses varying from 0·002 c.c. to 10·0 c.c. were injected into two animals each. The inoculation of the vaccine was followed by a distinct thermal reaction about the third day. A month was allowed for establishment of immunity, and on 28th March 500 and 1,000 M.L.D. of virulent cultures were injected into each of the pairs of vaccinated sheep.

The sheep which received a dose of 0·002 c.c. vaccine died of acute anthrax in 48 hours, of those which received 0·005 c.c., one died after being injected with 1,000 M.L.D. of virulent emulsion and the second sheep which received 500 M.L.D. of virulent culture survived. All sheep receiving a dose of 0·01 c.c. or higher survived.

These tests were considered to be very satisfactory as they indicated—

(1) That the vaccine was safe in administration up 10 c.c. to sheep.

(2) That a good immunity against the local elephant strain was produced by the bovine vaccine strain.

(3) The dose of vaccine required to protect against a standard dose of culture of 500 M.L.D. or 1,000 M.L.D., *viz.*, 0·01 c.c.

Tests on Cattle.

The vaccine was then tested out on cattle at the dose indicated in the previous experiments and multiples :—

3 cattle receiving 0·01 c.c. each.
3 cattle receiving 0·03 c.c. each.
3 cattle receiving 0·05 c.c. each.

The cattle were two years old, locally purchased animals which had been through rinderpest tests a short time previously.

All the animals exhibited a very marked thermal reaction of 2—4 degrees commencing on the day after the inoculation and persisting for about 48 hours. The animals were not visibly ill and did not go off feed. No swellings occurred at the site of the inoculation and after four days the animals were apparently normal. It was not considered necessary to test the immunity produced in cattle as experience in South Africa showed that, given a good reaction, a good immunity lasting 12—16 months was obtained.

The test indicated—

(1) That a standard dose of vaccine produced a good temperature reaction with rapid recovery.

(2) That multiples of the standard dose up to five times constituted a dose which was still safe for cattle.

(3) That the temperature reaction did not depend on the size of the dose given.

Preliminary Tests on Elephants.

It was now considered that the Laboratory tests were sufficiently conclusive to warrant the vaccine being tested out on elephants, and in consultation with the Manager of the Bombay Burmah Trading Corporation, a test was arranged in a small lot of three elephants at Pyinmana on 25th April 1929. The dose given was 0·01 c.c. of stock vaccine diluted to 1 c.c. for ease of inoculation.

Two of these elephants gave a definite thermal reaction and all recovered in a few days. A small local swelling appeared in two animals at the site of inoculation but this disappeared later. The site of inoculation was on the chest wall about midway between fore and hind leg at the level of the elbow. U Tun Hlaing, Research Veterinary Inspector, carried out the inoculations and superintended the experiment throughout.

Return of Special Reseach Officer to Africa.

While this test was in progress, the period of secondment of the Special Research Officer was approaching termination and it was necessary for him to return to South

Africa. The vaccine and stock emulsions, cultures, etc., were placed on ice until work could be resumed.

In the following month an outbreak occurred among elephants belonging to Messrs. MacGregor & Co., Limited, Toungoo, at Gwe Chaung. Vaccine was asked for and issued for the inoculation of three remaining elephants.

The inoculation was performed on 24th May by the firm's Veterinary Assistant, Mr. Birch, and inoculations were done in the neck. From the details submitted it is difficult to arrive at any satisfactory conclusion regarding this test. The test was carried in the presence of active anthrax infection and there was a possibility of one or other of the animals being already infected. A dose of carbolic acid had been administered 12 days previously and the vaccination was inadvertently done in the neck instead of on the side. One animal developed no thermal reaction but the remaining animals showed a marked rise in temperature 4—5 days after inoculation. In one of the animals the reaction was very severe (3·5° F.). The temperature of this animal returned to normal in 6 days but he was still definitely ill and getting weaker. The animal eventually died on the 13th day following the inoculation. The death was not attributed to anthrax and a *post-mortem* was held which supported this. Smears taken after death from the spleen and blood were returned negative from the laboratory. This case is difficult to explain except by presuming that there was some complicating factor which under the influence of the reaction due to the vaccination was able to produce a fatal ending. It certainly was not directly due to the vaccine or anthrax bacilli would have been found on examination of the spleen smears. The case may be regarded as an accident of vaccination such as is occasionally met with in the other species.

During July Messrs. Steel Brothers decided to have an experimental batch of elephants vaccinated at the Swa and arrangements were made for U Tun Hla-ing to do the inoculations and superintend the tests.

Nine elephants were injected with 1 c. c. anthrax vaccine (0·01 c. c. stock emulsion) under the skin on the chest wall on 2nd July and a further batch of 4 animals on 10th July, making 13 animals in all.

Most of the animals showed a temperature reaction between the 4th and 7th day after inoculation. Swellings of various sizes appeared from 2″ to 4″ in diameter but two animals developed dangerous swellings at the site of inoculation.

The clinical symptoms and thermal reactions had in all but one case subsided 14 days after the inoculation. Recovery from the local swelling in this case took about three weeks.

Results. In all tests up to this point 19 animals had been vaccinated and in the majority of cases a thermal reaction had occurred four to five days after inoculation.

Two animals showed large swellings at the site of the inoculation and one animal had died from some complicating factor.

These results were as good as could be excepted when it is considered that the inoculations were carried out under jungle conditions by men who had no previous experience in inoculation of elephants. The swellings were probably due to some contamination. The skin of an elephant is difficult to render sterile and the insertion of the needle requires a considerable muscular effort until one gets accustomed to it.

From these results it was concluded that the vaccine was safe for use in elephants in doses of 1 c. c. (0·01 c. c. stock vaccine.)

Return of Research Officer to Burma.

No further inoculation work was carried out in elephants between this date and the return of the Research Officer to Burma in October 1929.

The next step contemplated was the estimation of the degree of immunity, if any, produced by this vaccine on elephants. This phase of the work had already been discussed with the representatives of the timber firms at an informal meeting before departure from Burma and it was then accepted that an experiment involving a number of vaccinated elephants, inoculated subsequently with virulent cultures, would be necessary before the issue of the vaccine for general immunisation work could be considered.

Arrangement for the Crucial Test.

At a combined meeting on October 31st. 1929, representatives from four firms agreed to share the cost of the animals for the experiment and the incidental expenditure in connection with transport and supervision.

A site was suggested on the Toungoo-Thandaung road at Shwenyaungbin as suitable for the test as it provided the conditions laid down of (1) good water, (2) good fodder for the animals, (3) no cattle or buffaloes in the vicinity, (4) plenty of timber for cremation of carcases and (5) convenient to the main line. This area was inspected and approved. The decision to use virulent cultures of elephant strain anthrax on the animals in this test and the anticipated deaths in control animals from anthrax necessitated the strictest care and supervision at every stage of the experiment in order to prevent permanent infection of the site by the disease.

A retest of the vaccine which had been in storage for eight months was made on six 2 years old cattle at the Research Laboratory in November 1929 when it was found that the vaccine was active, although it did not give rise to so acute

a reaction as had been produced in cattle at the former test in April of that year. The virulent spore emulsion was retested and found to be unchanged.

The elephants selected for the crucial tests were two males and two females for immunisation and two crock elephants as controls—all full grown animals. Two goats were also procured for initial control experiments.

To gain as much information out of the experiment as possible, the immunisation of the four elephants was done by four different methods. The inoculations were done personally by the Special Research Officer. The test was commenced on December 3rd, 1929.

Inoculation of Vaccine.

Elephant A—2 c. c. vaccine on two occasions at an interval of 14 days (2 c. c. double).

Elephant B—1 c. c. vaccine on two occasions at an interval of 14 days (1 c. c. double).

Elephant C—2 c. c. vaccine on one occasion (2 c. c. single.).

Elephant D—1 c. c. vaccine on one occasion (1 c. c. single).

All the elephants gave a definite thermal reaction from the first inoculation commencing about the fourth day and being maintained a few days after which a normal temperature was shown. There were no large local swellings, the average size being about 4" diameter. No reaction was shown after the second inoculation in the two animals which received a double dose.

A month was allowed to elapse from the date of the second inoculations for the development of immunity.

Estimation of dose of Virulent Emulsion required to kill an Elephant.

Before testing out the vaccinated animals with virulent spore emulsion, it was essential to know whether a dose of 1,000 M. L. D. would be sufficient to kill an elephant.

A control elephant (E) and goat (I) were therefore given a dose of 1 c. c. of virulent spore emulsion, equivalent to 1,000 M. L. D. for sheep, on January 20th.

The goat died of anthrax in 36 hours and the elephant on the 6th day after inoculation. The diagnosis was made on the spot by microscopic examination of the blood. The carcases were then cremated.

Test on Immunised Elephants with Virulent Emulsion and Results.

Elephant A and the remaining control goat (II) were given an inoculation of 1,000 M. L. D. of virulent anthrax on January 26th. The control goat died in 30

hours from microscopically diagnosed anthrax. Elephant A developed a local swelling about 3″ in diameter which persisted for a few days but otherwise showed no effect from the inoculation.

The elephant A presumably possessed the strongest immunity of all the inoculated elephants having been given the largest dose of vaccine (4 c.c.).

As no ill effects were shown in this animal and as it was desired to push the test to a conclusion as soon as possible. the remaining elephants B, C, D and one non-inoculated control elephant F were injected with virulent spore emulsion on February 7th, the vaccinated elephants receiving 1,000 M.L.D. and the control F 500 M.L.D. or half the quantity administered to the first control elephant E.

Elephants B and D showed a slight temperature reaction within 48 hours after the inoculation. elephant C remained normal. No local swellings developed and the animals remained perfectly fit.

The control elephant E developed an enormous swelling at the site of the inoculation on the 3rd day and death from anthrax occurred on the fourth day.

Conclusion of the Test.

The remaining four elephants were discharged from experiment on February 23rd and experiment concluded.

Notes on the Test. The dose of virulent culture (1,000 M.L.D.) which the vaccinated animals received was many times greater than would ever be met with in the infected areas in the jungle. The incubation period under natural conditions is estimated at about 10 days and half the dose (500 M.L.D.) given to the second control elephant showed an incubation period of three days and death in four, we can therefore assume that the immunity would be sufficient to protect against any natural infection.

The absence of swellings in the vaccinated animals at the site of the inoculation was probably due to care in sterilization of the skin and to having the animals under good control in a specially erected crush pen which facilitated the operation of inoculation.

It will be noted that on each of the three occasions when virulent material was inoculated, a control (non-vaccinated) animal was also injected, so the results may be accepted as definitely conclusive.

It is remarkable that quite as good an immunity resulted from the single dose of 1 c.c. as for the double dose of 2 c.c., but when it is remembered that the vaccine is an emulsion of living spores which are capable of multiplying in the tissues on injection, the quantity of material originally injected requires only to be enough to set up a local focus of infection and start the immunising process.

Conclusions.

From the results of the test on elephants at Shwenyaungbin, the following data has been obtained :—

1. The period of incubation in experimentally produced anthrax in elephants varies from 3 to 6 days.

2. Vaccine prepared from the South African bovine strain anthrax is safe for use in elephants in doses up to 4 c.c.

3. Doses of 1 c.c. and over give an absolute protection against a dose of 1,000 M.L.D. of virulent elephants strain anthrax after a period of 30 days.

4. With care in carrying out the inoculations, the risk of producing local swellings is very slight.

5. The most satistactory site for the inoculation of anthrax into elephants is on the chest wall just clear of the play of the shoulder at the level of the elbow joint.

CATTLE TESTS.

While these tests were in progress at Shwenyaungbin the cattle on the Agricultural College farm, among which there had been a case of anthrax some time previously, were inoculated with 1 c.c. of vaccine each.

No temperatures were taken, but it was not possible from the general appearance of the animals during the next 14 days to note any departure from the normal. In the milch cows there was no appreciable drop in milk secretion although this was anticipated.

The following animals were vaccinated on the dates indicated :—

17th December 1929—		
Bulls	5	
Cows	10	
Heifers	5	
Heifer's calf	1	
Working bullocks	31	
	52	52
24th February 1930—		
Bullocks	16	
Cows	2	
	18	18
		70

Conclusions.

These results in cattle when considered with the previous Laboratory tests indicate that the use of the anthrax vaccine is safe in cattle. It is not considered necessary to test out the immunity against a dose of virulent emulsion as it is considered that a good protection is given.

BUFFALO TESTS.

It was considered desirable to test out the action of the vaccine on buffaloes as these animals frequently contract the disease and are undoubtedly a source of danger to the elephants working in the adjoining forests. Great difficulty was experienced in getting suitable animals for a test in the Insein area. The majority of the buffaloes kept in this area are of the Indian type of milch buffalo.

The problem was discussed with one of the members of the firm of Bombay Burmah Trading Corporation (Mr. Phillips) and he kindly offered to place 12 animals at our disposal for a test, on the basis of payment for any animals which died as a result of the inoculation.

This was accepted and a test on a mixed lot of twelve young and old animals was carried out at Alegyun on February 24th, 1930. The vaccine used was the same as that employed in the test on cattle and elephants in doses of 1 c.c.

The result of the inoculation was very satisfactory. All the animals developed a temperature reaction about the fourth day, becoming normal two to three days later. One aged very thin buffalo developed a severe reaction and was off feed for one and half days but recovered rapidly. The reactions resembled those given by cattle during immunisation.

Conclusions.

From these results, and taking into consideration the results in the allied species, it is considered that anthrax vaccine is safe for use in buffaloes. The question of degree of immunity is not at the moment of great importance, but this may be tested out later if break-downs after vaccination are reported.

GENERAL REMARKS ON THE TESTS.

The vaccination against anthrax of the three species of draft animals—elephant, cattle and buffaloes—has given very promising results in Laboratory and field experiments.

These have demonstrated that a vaccine prepared in Burma from attenuated strains is safe to use, and in those animals (sheep and elephants) which were tested out for the immunity produced, the results exceeded expectations.

Proposals for the Future.

The question of introducing the vaccine for general immunisation of animals in the infected areas can now be considered at the next step, and arrangements are in progress for the inoculation of a number of elephants in the danger zones during the approaching hot weather " rest period ".

Inoculation of cattle and buffaloes against the disease will give rise to considerable difficulties as there is no provision for compulsory inoculation against any disease in the Cattle Disease Rules and only in the presence of an epidemic will the villager consent to any inoculation being carried out on his animals. Inoculation with anthrax vaccine under these conditions is not to be recommended.

Vaccination against anthrax is a preventive and not a curative measure and should be done as an annual routine procedure, otherwise its value as a prophylactic is not made full use of. Inoculations carried out in the presence of active infection, in animals not previously vaccinated, are associated with considerable risk of transmission of the disease to healthy animals by the operator's needle. Deaths under these conditions, due to natural infection, would, in the majority of cases, be attributed to the vaccine.

Until powers are available for compulsory inoculation of cattle and buffaloes at any time it is considered necessary, little progress in connection with the control of the disease in village herds can be hoped for.

Although the results in the Laboratory tests were considered satisfactory and conclusive, it is realized that the final test of the efficacy of the vaccine will be the results during the coming anthrax period (April to July) in vaccinated animals working in the infected areas.

It is hoped that the inoculation of a sufficiently large number of elephants will be completed this year before this period to allow of reliable data being obtained for comparison with figures for the same areas in previous seasons.

Duration of degree of Immunity.

It is the experience, in immunisation of animals against anthrax, that immunity lasts about 12—16 months. It is customary therefore to repeat the vaccination at 12 monthly intervals.

This is essential because an area once infected with anthrax remains so almost permanently. The spores, the infective agent, are highly resistant and are known to remain active for over 30 years.

Under ordinary conditions this annual inoculation is all that is necessary to prevent mortality, but if the area is grossly infected or if an outbreak among non-protected animals occurred in the neighbourhood, it would be necessary to re-inoculate for the sake of safety at intervals of six months.

The question of duration of the immunity elephants may be tested out in the future when arrangements can be made, and if it is considered that a test is necessary. At present there is no intention to do so as it would involve considerable expense for which there is no justification.

Keeping Qualities of the Vaccine.

The vaccine is a very stable product and under good storage conditions will remain unaffected for a considerable period. No difficulty should be experienced with regard to its distribution in the jungle areas where it will be used, as it will keep for about two months after issue from the Laboratory if protected from light and heat.

Inoculation of Herds.

The operation of vaccination is a very simple procedure and can be performed by any one having a knowledge of general principles of sterilization and asepsis. It is proposed therefore to train forest assistants in the various timber firms, etc., which will require to have large numbers of animals vaccinated annually in this work, by a series of practical demonstrations now being arranged. This will relieve the Civil Veterinary Department of the responsibility for having to arrange for these annual inoculations in the future. With the present staff at our disposal it would be impossible to undertake this work on firm's elephants in the forest areas, but selected members of the Veterinary Staff will be trained in the work so that they will be able to deal with animals in infected areas in their districts.

Supply of Vaccine.

A sufficient supply of tested vaccine is available to meet all requirements during this season 1930-31, but it will be necessary to make provision for the season 1931-32 during this present year.

The Special Research Officer having now taken over control of the Department, it will not be possible for him to devote any lengthy periods of time to research work and it is hoped that from among the applicants for the posts now being advertised it will be possible to select one having the requisite Laboratory experience to carry on this work.

ANTHRAX IN HORSES.

No Laboratory tests have been carried out in regard to the immunisation of horses against this disease.

Horses are highly susceptible to anthrax, much more so than cattle or elephants, and a vaccine suitable for immunising this species would require to be specially made and of a very low degree of virulence.

The cost of preparing a vaccine is mainly the cost of the experimental animals used, and if only a small quantity was necessary the cost of production would be prohibitive.

The distribution of the disease in horses appears to be limited to the Insein District and the number of animals which would be submitted for vaccination would be comparatively few. Under these conditions it is considered that it would not be economical to maintain a stock of vaccine suitable for horses. If however it can be shown that the cost of production would be justified, a stock could be prepared in the future.

CONCLUDING REMARKS.

The assistance which has been given by firms and individuals during the last couple of years while work on this problem was in progress is most gratefully acknowledged, in particular the help and encouragement which was received on many occasions from members of the Bombay Burmah Trading Corporation. The arrangements for carrying out tests in elephants and buffaloes were organised by this firm and no trouble or expense was spared to make the arrangements as perfect as possible. To Mr. Wroughton and Mr. Prior must be given the credit for making these tests possible.

The public spirited action of the four contributing firms in putting up elephants for the test will be recognised as highly commendable when it is realized that had the tests been unsuccessful they would have lost, in elephants alone, a sum of approximately Rs. 30,000.

The local arrangements for the test at Shwenyaungbin were dealt with by Messrs. MacGregor & Co., Toungoo, who willingly seconded their Veterinary Assistant for the duration of the tests at considerable inconvenience. The work of this officer, Mr. Birch, was very highly appreciated. He was in sole charge of the camp until the work with virulent anthrax was commenced and rendered invaluable aid throughout in the control and management of the elephants and their attendants, erection of crush pen for inoculation and cremation of the carcases of the animals which died.

The developments during this coming season in immunised animals will be awaited with interest, and, in view of the results herein recorded, with a considerable amount of confidence.

CLINICAL NOTES.

An Interesting Case of Cystic Calculi.

(With Plate VI.)

A Sahiwal stud bull, eight years old, while in active service, suddenly showed acute symptoms of colic, on the morning of the 9th October, 1930. I suspected acute digestive trouble and full dose of linseed oil with spt. ammonia aromaticus was administered and the bull was given gentle walking exercise. After three hours, finding no relief and the pain getting severer, another dose of oil was administered with the same result. The temperature and pulse were normal, but the respiration was laboured. Defecation and urination were arrested. A full dose of magnesii sulph. with spt. ammonia aromaticus and tinct. belladona was administered and warm soap water enema was given in the afternoon at 3 P.M. A small quantity of soft dung was passed and the animal looked a bit relieved, but there was no attempt to urinate, which drew attention to some obstruction in the urinary tract and treatment was directed to stimulate the urinary apparatus to perform its held up function. The bull was given internally repeated doses of dieuretics and blankets wrung out in hot water were applied to the loins. He passed a small quantity of urine on the 10th morning, at about 11 A.M., after which he did not even attempt to urinate till he died, although all medicinal treatments were tried up to the end. Palpation of the bladder from the rectum showed that it was full and the animal evinced pain on pressure. The bull appeared spiritless, ceased to eat or drink, the pulse quickened latterly and the expiration became prolonged and painful. There was considerable oedema of the dewlap and brisket ; the animal broke into profuse sweat and ultimately died of uraemic poisoning on the 15th morning. The obstruction was suspected to be in the urethra, as the bladder was full on palpation. It was diagnosed as calculi which had escaped from the bladder into the sigmoid flexure of the penis which is especially predisposed to this accident owing to the narrowness of the lumen and tortuous course of the canal—the stones having been intercepted in their course from the bladder at the outward or first flexure of the urethra above and in front of the scrotum. In consequence of the great difficulty in reaching the calculi when lodged about the flexure and apprehending possible rupture of the already over distended bladder, a surgical operation was deemed inadvisable. The bull's temperature on the 14th evening was 100°·2F. and 15th morning 100°F. and he did not show any alarming symptoms until a few hours before death. Accumulation of urine in the bladder produces in the more sensitive

PLATE VI.

Fig. 1. Calculi found in the bladder and urethral canal.

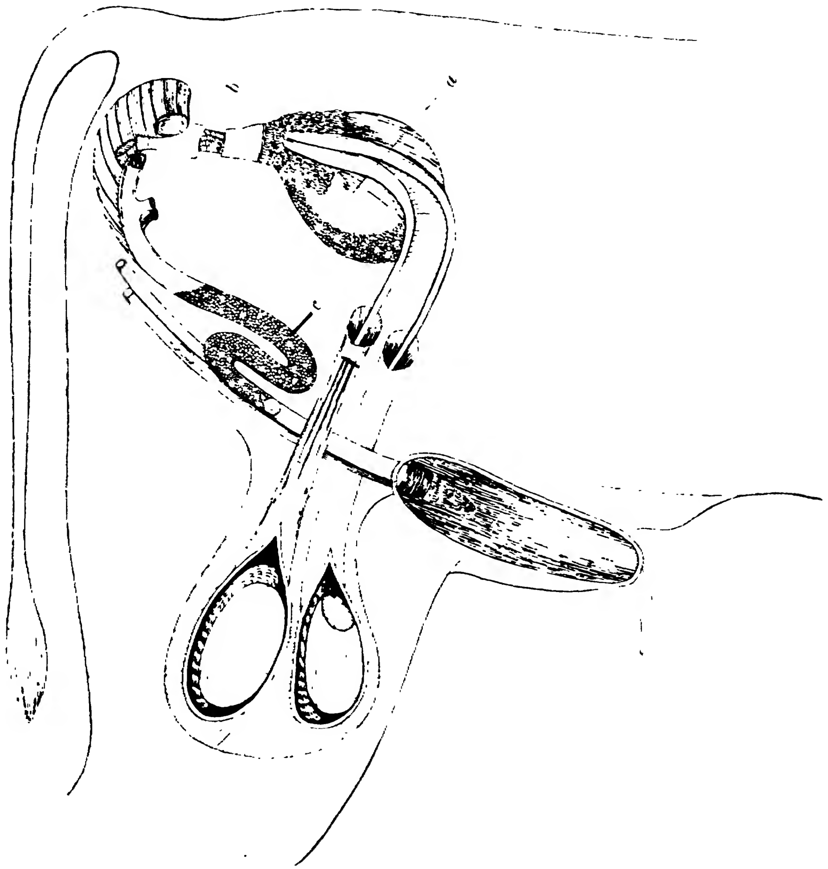

Fig. 2. Showing the position of calculi in the bladder (*a*), urethral canal (*b*) and the sigmoid flexure (*c*).

animals, such as horses and dogs, very early signs of discomfort and pain, whereas in the indolent ruminant, especially bulls several days may elapse before any characteristic symptoms are noticed.

On *post mortem* the bladder which was intensely congested with diptheritic centres all over was found still full. The whole urinary canal from the bladder to the end of the penis was dissected out intact and cut open. On the floor of the bladder were found numerous round bodies varying in size and shape from Snipe shot to Buck shot with a shining metallic surface (Plate VI). Similar bodies were found all along the course of the urethra ; and the sigmoid flexure was choked with these round bodies of varying sizes (Plate VI). One of the largest size was found lodged in the lumen, 4 inches below the second flexure and this was the cause of complete blockade of the flow of urine from the bladder. The kidneys were highly congested, and the cortical portion of the right kidney showed fatty degeneric centres. The other organs showed more or less pathological changes, and interstitial oedema due to uraemic poisoning. The death resulted from uraemia from retention of urine in the bladder for a week owing to the serious obstruction caused by calculi. The calculi was analysed and found to be chiefly composed of calcium carbonate. These are due to an excess of salt in the urine caused by drinking water containing too much lime or eating food too rich in lime and magnesia.

The calculi weighed 4 drachms and 40 grains. The shining metallic colour when removed from the bladder was due to the coating of urobilin, the colouring matter present in the urine accumulated in the bladder. This metallic lustre disappeared after exposure and drying. The indolent habits of Sahiwal bulls serve as predisposing causes to this trouble. In places where the soil and water are rich in lime, it is essential to examine the urine of the stud bulls as they advance in age, and if any deposits or sediments are noticed to give them acidulated water (dilute hydrochloric acid—2 drachms) in drinking water occasionally. In human beings the similar deposits occur but generally people drink water after boiling and they take sufficient acids in their food which cause the calcium salts to dissolve and pass off in the urine. Plate VI, fig. 1 shows the varying size of the calculi found in the bladder and all along the course of the urethra and Plate VI, fig. 2 shows how the sigmoid flexure was choked with these calculi [L. S. Joseph].

The first case of Simple Monstrosity in the Pusa Dairy Herd during its existence of over 20 years in Pusa.

(With Plates VII and VIII.)

This was a case of simple monstrosity with combination of the second order "Nanomelus Brevis" (all limbs and ears and tail short) and third order "Labium Leporinum" (harelip), with spina bifida (division of the spinal column) and

" Anasarca " (fluid beneath the skin). A half-Ayrshire-Sahiwal cow, Vida No. 170, aged about six years in calf 7½ months to a Montgomery bull, Moti No. 368, which died recently from uraemic poisoning, after her three previous normal calvings and normal healthy calves, threw her still-born monster heifer calf on the morning of the 19th October, 1930, without any undue straining or exertion on the part of the mother. From the size of the foetus as seen from Plates VII and VIII, one would wonder how the process of expulsion was effected so easily without any external help. The explanation is, that the connective tissue of the entire body of the foetus from head to the croup was infiltrated with serum, and the young creature although in appearance double the size of an ordinary calf and weighing 50 lbs. was quite supple, and the rent in the spinial column facilitated the expulsion without any external aid.

General appearance.

The body of a wild boar with short legs, ears and tail, the head of a lioness, enormously large, short face and hare lipped. There was a rent of 4 inches on the back behind the withers.

The *post mortem* revealed a large quantity of serosanguineous fluid in the abdominal and thoracic cavities and similar fluid was found under the skin. The spine appeared broken, having a gap of 4 inches, between the end of the cervical and the beginning of dorsal regions and the spinal chord was found as if torn asunder and hanging. The other organs were normal and perfectly developed.

In India people believe that the appearance of monstrosities in domestic animals is due to the influence of enraged gods, and they are regarded with fear or horror. Some regard them as prodigies, or freaks of Nature, and describe them as marvels or curiosities, but scientifically they are simple modifications, or irregularities in the development of organs of the foetus in utero. The embryo of the domestic animals, in arriving at its ultimate development, appears to pass through all the degrees of organization which mark the different types in the zoological series. The embryo has been submitted to some kind of alteration ' in utero ' and this has been produced during the interval between conception and birth [L. S. Joseph].

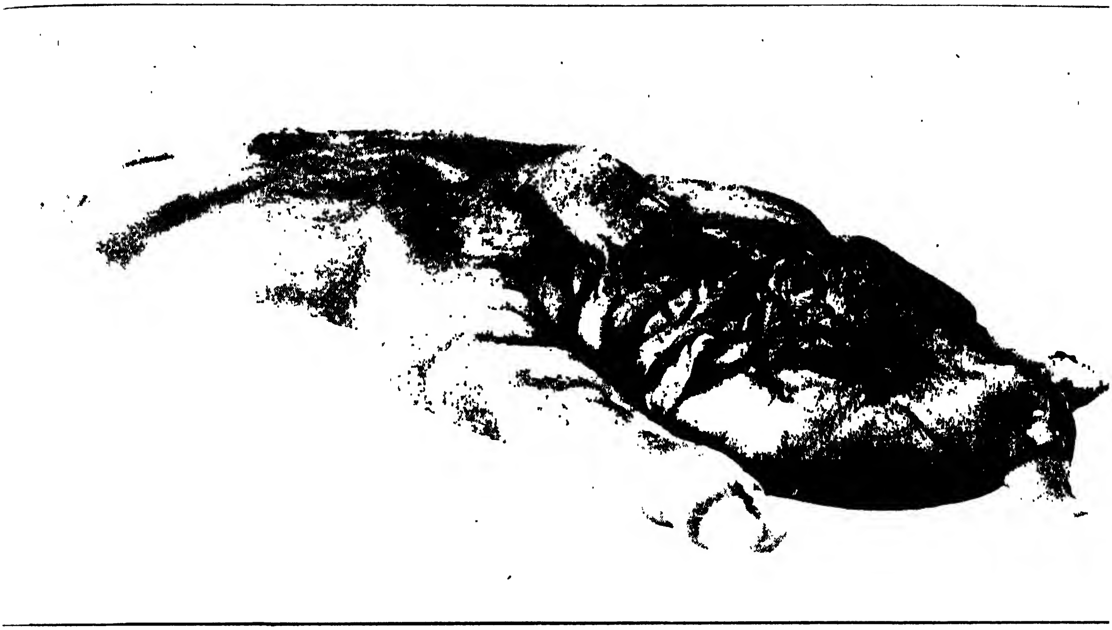

Fig. 1. Showing the head.

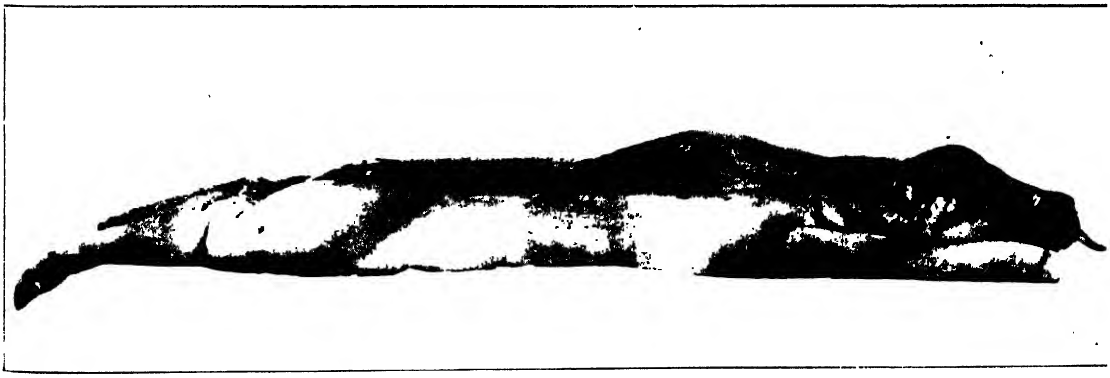

Fig. 2. Showing the whole length of the body.

A CASE OF SIMPLE MONSTROSITY IN PUSA DAIRY HERD.

Fig. 1. Showing the hind legs and tail.

Fig. 2. Standing posture

ABSTRACTS

The Inheritance of Butter-Fat percentage in Crosses of Jersey with Red Danes.—CHR. WRIEDT. (*Journal of Genetics*, Vol. 22, No. 1, April 1930.)

In an article, published posthumously under the above title, the author draws attention to the danger which clearly exists that the occurrence of variations due to living conditions, as well as others due to non-geneti·al causes, may be overlooked, and supports the conclusion, which has been drawn by experienced live-stock breeders, that practically all the economically important characteristics of our domesticated animals depend upon a complicated reaction; between heritable factors and the conditions under which the animals live, while there are other variations the causes of which we do not yet know.

It is well known that precise genetical analysis of heritable factors of economic value in such slow breeding animals as cattle is extremely slow and expensive and it is obvious that properly controlled experimentation, on a scale sufficiently large to warrant definite conclusions, presents obstacles which are practically insuperable. It is, therefore, natural that no great progress has been made in the analysis of the economically important characteristics of even the principal milk breeds and clear instances are cited in this article in support of the necessity for accepting non-genetic variability, which has nothing to do with living conditions. It is pointed out that butter-fat percentage in milk obviously depends on the fodder to a great extent. Exercise and conditions of mating of the cows also produce a great deal of variation not influenced by heredity, and the author states that to this must be added the possibility, perhaps indeed the probability, of other variations, the causes of which are unknown.

A critical analysis of the heredity of butter-fat, in various crosses between Jersey and Red Danish cattle, is made in this article, and the following conclusion is drawn, *viz.*:—

"As a result of the investigations I state as conclusion that all data seem to indicate that one genetic factor exists which causes the difference in content of butter-fat in the milk of the Jersey and Red Danish breeds. This genetic factor varies in its effect, but the effect is equally great whether it meets a gene for high or low percentage butter-fat. Besides this, it is possible that some of the Jersey bulls used in the experiment had a modifying factor which caused an increase in butter-fat percentage, but the existence of this factor has not yet been definitely proved." [A. O.]

Un nouveau médicament pour le traitement des piroplasmoses. (A new drug for the Treatment of Piroplasmoses.)—A. THEILER. (*Bull. Soc. Path. Exot.* 1930. May 14, Vol. 23, No. 5, pp. 506-529. With 22 text-figs.)

The author points out that trypanblue has had a wide application in the successful treatment of piroplasmosis both natural and experimental. But, more particularly since the war, there have appeared on the market substances called trypanblue which not only are devoid of any parasiticidal action, but are liable on injection even by experienced persons to produce alarming symptoms of shock. In the course of a tour in Queensland two years ago Theiler heard it said that trypanblue was quite useless for the treatment of red-water as it occurred in that country.

This fact caused the author to decide upon the publication of the results which he obtained at Onderstepoort in 1925 and 1926 with a new drug which he calls "Piroblue". The experiments carried out in the Sandoz laboratories by Muller have shown that the parasiticidal action of stains such as trypanblue and others can be greatly increased if they are combined in an appropriate form with the bile acids. This combination can be effected without producing any proportional increase in their toxicity.

The bile acids and their salts possess no parasiticidal power of their own, but their association with pure trypanblue renders it possible to reduce the dose of the drug to a point at which toxicity does not come into consideration at all. Not only so, the parasiticidal action is actually increased.

According to Stoll, the explanation of this effect is probably as follows: Bile acids exert a profound effect upon the surface tension of liquids containing them. This fact is made use of commercially in dyeing, and this property enables drugs combined with them to come into closer contact with parasites.

Two compounds, which are called T18 and T19 were used for experiment. These were composed of the pure dye and sodium cholate in different proportions. These compounds possessed similar properties, and it was decided to make one intermediate in composition between these for commercial application.

The toxicity of "Piroblue" was tested upon mice, but, in spite of the use of a large series of animals (nearly 100) the results were, for some unknown reasons, discordant.

A series of guinea-pigs was placed under test by intravenous injection. In the majority of cases a 5 per cent. solution was used, and doses were graduated so as to give 0·1 g. per kg. upwards. In this series concordant results were obtained, and the toxic dose by intravenous injection was found to be 0·19 g. per kg.

Full details are given of twelve observations carried out on pure-bred Polled Angus cattle, five upon African native bred animals obtained from areas free from piroplasmosis, and five upon horses. Four of the latter were animals undergoing hyperimmunization against horse sickness, the other a sporadic case. One of the animals was infected with *P. caballi*, and the other four with *Nuttallia equi*. The whole of the seventeen bovines used were infected artificially with *P. bigeminum*. Of the twelve Scotch animals six developed haemoglobinuria as did also two of the African cattle. The blood used was therefore of considerable virulence. The majority of animals also developed high fever.

Both compounds T18 and T19 were used, in 1 and 2 per cent. solutions, and doses of 100 c.c. for adults and 50 c.c. for calves were given intravenously. In no case was any evidence of shock observed. One of the African cattle was given 50 c.c. of 4 per cent. solution of T18 without producing trouble of any kind.

In *every case* the temperature promptly fell and parasites disappeared from the circulation within 24 hours, and there was a *rapid* and *surprising* improvement in condition. In one case death occurred, but the calf in question should not have been put under treatment, as it was suffering from a paratyphoid infection.

T18 and T19 do not produce complete sterilization as is shown by the fact that in eight instances parasites reappeared in the blood in small numbers some days after their first disappearance. This is not an undesirable result, because premunization against piroplasmosis depends upon the persistence of the parasite in the blood. The new drug is suitable therefore for use in the premuni-

tion of animals, and it can be given without risk to valuable imported animals. The possibility using solutions up to 4 per cent. strength permits of a reduction in the amount of liquid injected reasonable proportions.

Until further experimentation has furnished fuller information, Theiler recommends the following doses:—

For calves or slight cases:—

50 c. c. of a 2 per cent. solution in water.

or 100 c. c. of a 1 per cent. solution in water.

For serious cases in adult animals:—

50 c. c. of a 4 per cent. solution in water.

or 100 c. c. of a 2 per cent. solution in water.

All the animals treated in the experiments had been infected by the injection of virulent blood, it the author sees no reason why similar results should not be obtained in naturally contracted ses.

The four cases of equines infected with *Nuttallia equi* were all cured, but Theiler recommends ution for the time being in drawing conclusions as to the efficacy of the drug against this parasite. he first case treated was a severe one and two injections were necessary to cause the disappearance the parasites. In the other cases the disappearance of the parasites was not immediate, and the mperature remained high for 24 hours after the injection. It must, therefore, be concluded that e drug is probably less active against Nuttallia than against Piroplasma. The fact that a case of ttalliasis with haemoglobinuria recovered after two injections is sufficient to recommend the use of e drug, more particularly because up to the present no known drug has been of any value for the eatment of this condition.

It is suggested that Pirobluo will probably prove effective against canine piroplasmosis and gainst diseases caused by Babesiella, but the author notes, without giving any details, that it is uite without action on *Theileria parva* and Anaplasma. (Reprinted from *Tropical Veterinary ulletin*, Vol. 18, No. 4, December 1930.)

Feeding standards for dairy cows.- E. T. Halnan, M.A.

The following suggested standard for dairy cows is taken from an article on the "Feeding andards for Dairy Cows", by E. T. Halnan, M.A., School of Agriculture, Cambridge, published the *Journal of Dairy Research*, Volume 1, No. 1, dated November 1929. The full article should, owever, be read by those interested in the subject.

A suggested standard.

From the evidence given in this monograph it would appear that a suitable standard for milk oduction would be:—

(1) For maintenance of the 1,000 lb. cow: 5,446 cals. net energy, or 5 lb. starch equivalent, containing 0·5 lb. digestible protein or 0·6 lb. protein equivalent.

(2) For the production of 1 gallon of 4 per cent. fat milk: 2·5 lb. starch equivalent or 2,777 cals. net energy, containing 0·48 lb. digestible pure protein or 0·57 lb. protein equivalent.

Based on Anderson's formulæ, the requirements for milk of various fat percentages would be per gallon :—

Fat per cent.	Composition of milk		Food requirements		
	Protein	Calories	Digestible pure protein	Protein equivalent	Starch equivalent
2·5	0·271	2,646	0·40	0·48	1·9
3·0	0·294	2,903	0·42	0·50	2·1
3·5	0·316	3,160	0·45	0·54	2·3
4·0	0·338	3,417	0·48	0·57	2·5
4·5	0·360	3,674	0·52	0·62	2·7
5·0	0·383	3,931	0·55	0·66	2·9
5·5	0·405	4,188	0·58	0·69	3·1
6·0	0·427	4,445	0·61	0·73	3·3
6·5	0·450	4,702	0·64	0·76	3·4
7·0	0·472	4,959	0·67	0·80	3·6

Sur l' adaptation des trypanosomes à l' homme. [The Adaptation of Trypanosomes to Man.]—F. Mesnil. *Bull. Soc. Path. Exot.* 1930, July 9, Vol. 23, No. 7, pp. 719—721.

Mesnil gives reasons for thinking that the occasional cases of infection of human beings with purely animal trypanosomes are due to some special condition of the individual.

The case recorded by Vaucel supports the view that *T. rhodesiense* is in reality *T. brucei* adapted to man. On the other hand, the observation made by Mesnil with Ringenbach in 1911, that in the laboratory *T. rhodesiense* rapidly becomes susceptible to the action of human serum, led him to think that *T. rhodesiense* was of recent adaptation to man.

The facts indicate that this adaptation may be purely accidental, and that no doubt is the reason why *T. rhodesiense* occurs sporadically.

A practical conclusion that is drawn is that all kinds of trypanosomes should be handled with the greatest caution. The chances of infection may be slight, but they are nevertheless real. (Reprinted from *Tropical Veterinary Bulletin*, Vol. 18, No. 4, December 1930.)

Action of Formaldehyde on the Aggressive Substance of Blackleg Filtrate, Bacterin and Aggressin.—Joseph P. Scott. *Jour. Inf. Dis.*, xlvi (1930), 6, p. 460.

Concentrations of 0·5 per cent. formaldehyde increased blackleg aggressin, filtrates and bacterins to their greatest potency. The increase in potency produced in these products is dependent on the amount of aggressive substance developed in the culture from which the product is made. Formaldehyde apparently acts on the aggressive substance in a quantitative manner. The presence

or absence of bacterial cells in the product has no effect on the potency. It is shown that the amount of growth, the production of aggressive substances and the pathogenicity of a blackleg culture are independent. Virulent blackleg cultures consists of three parts: (1) living bacterial cells, (2) aggressive substances or products of growth produced during the development of cultures of *Clostridium chauvaei* and (3) a lethal substance or specific activity of the virulent bacterial cells. Potent blackleg products should have a potency of at least 20 aggressive units per dose. By the use of certain mineral salts and of the proper amount of formaldehyde, blackleg filtrates and bacterins having potencies of 130 and 260 aggressive units can be produced. Formaldehyde inhibits the agglutinogen but increases the activity of the protective antigenic complex. (Reprinted from *Journal of the American Veterinary Medical Association*, New Series, Vol. 30, No. 5, November, 1930.)

Eleventh International Veterinary Congress, London, August 4th to 9th, 1930.—(From The *Journal of Comparative Pathology and Therapeutics*, Vol. XLIII, Part 4, December 1930.)

RESOLUTIONS.

At the closing meeting of the Congress, held on Saturday, August 9th, 1930, the following Resolutions were passed.

I. *Official Languages.*—That for future Congresses the official languages remain as at present, *viz.*, English, French and German, but that, if found possible, the summaries of reports may be translated also into Italian and Spanish.

II. *Date and place of Next Congress.*—That the invitation of the American Veterinary Medical Association for the next Congress to be held in the United States of America, probably at Boston in the year 1934, be accepted.

III. *Foot-and-Mouth Disease.*—That, in the opinion of the Congress: –

(*a*) The establishment of the existence of a plurality of viruses foot-and-mouth disease is of the highest significance in relation to the epizootiology of the disease and to methods of active and passive immunization.

(*b*) It is highly desirable that in all countries the type of virus present should be determined in all primary outbreaks.

(*c*) In respect of disinfection, it should always be remembered that both the diseased animals and the buildings constitute a serious danger in the spread of the disease.

(*d*) The most efficient disinfecting agents are moist heat and sunlight and, of chemical agents, potassium and sodium hydrates and formalin.

(*e*) The value of passive immunization has been established, and its use in practice in favourable circumstances is to be encouraged.

(*f*) It is highly desirable that all possible efforts should be made to discover an efficient method of active immunization.

IV. *Infectious Abortion of Sheep, Cattle and Swine.*—(*a*) That scientific investigations regarding contagious bovine abortion are essential in all civilised countries, particularly for the purpose of controlling the disease, the preparation of an effective method of immunization, the elucidation of the rôle of *Bacterium abortus* Bang as a cause of disease in man, and determining the relationship between the disease caused by this organism in man and Malta fever.

(*b*) That, in view of the very widespread occurrence of infectious abortion of cattle in all civilised countries, an international scientific investigation should be carried out, and that such an investigation would come within the purview of the office International des Epizooties de Paris.

V. *Relationship of the Veterinary Surgeon to Animal Husbandry.*—That, in view of its importance to the welfare of the public, Animal Husbandry (Zootechny) should be given a prominent position in the programme of every future Congress.

VI. *Veterinary Science in Relation to Public Health, with special Reference to Production and Distribution of Meat and Milk.*—That at the next Congress a special Section for Meat and Milk Hygiene should be created.

VII. *The Law Governing the practice of Veterinary Medicine and Surgery.*—(*a*) That the Congress urges upon Governments the necessity for legislation giving to the veterinary profession such power as will enable it to exert a uniform control over the health of domestic animals.

(*b*) That the title of Veterinary Surgeon ought to be legally protected, and that only those should be authorised to practise animal medicine who possess a diploma granted or recognised by the State.

VIII. *Anthrax.*—(*a*) That in the general interest of Public Health in all countries it is an indispensable duty to take effective precautions against the infection of human beings and animals with Anthrax by animal products, such as bones, bonemeal and hides, containing the germs of the disease.

(*b*) That regulations are urgently needed to prevent the trade in raw materials from animals dead of Anthrax. If the laws in force in an exporting country are not sufficient for this purpose, it is essential that the suspected products should be tested or sterilised in the importing country before they are allowed to pass into general trade.

(*c*) That only an exposure to steam under pressure for several hours can at the present time be considered satisfactory for the thorough disinfection of animal products infected with Anthrax.

IX. *Standardisation of Biological Products.*—That the attention of the office International des Epizooties de Paris be drawn to the urgent necessity of a prompt consideration of the question of the standardisation of biological products.

X. *Diseases of the New-born.* That, having regard to the good results of the organisation for combating diseases of the New-born in Germany, the Congress recommends that in all countries similar organisations should be established, with a view to the formation of an International Union for that purpose, to which each country would furnish annual reports for circulation to all countries concerned.

XI. *Rinderpest.* That this Congress considers that sufficient knowledge of practicable methods is now available to eradicate Rinderpest within a resonable period of time in any country which will provide adequate facilities for their application, and urges upon all Governments to co-operate to this end.

XII. *Fowl Typhoid and Bacillary White Diarrhœa,*—That, in the opinion of this Congress, the method of diagnosis and prophylaxis of Bacillary White Diarrhœa of Chickens by systematic agglutination tests, carried out by qualified veterinarians, is at the present moment the procedure most to be recommended.

XIII. *Genetics.* (*a*) That Veterinary Schools and Veterinary Institutes should be provided with the scientific and experimental facilities necessary for the proper teaching of Zootechnics.

(*b*) That the necessary funds for carrying out experimental researches should be accorded to the teaching staffs.

(*c*) That as far as possible the services of Veterinary Surgeons should be utilised in applying the measures designed to improve animal husbandry.

Rinderpest in Goats in Nigeria.—W. G. BEATON, M. R. C. V. S.

The following summary of an article on "Rinderpest in Goats in Nigeria", by W. G. Beaton, M. R. C. V. S., Research Officer, Veterinary Laboratory, Vom, N. Nigeria, published in the *Journal of Comparative Pathology and Therapeutics*, Vol. XLIII, Part 4, December, 1930, pp. 301-307, I think, is of great practical interest to those engaged on rinderpest control in India :—

SUMMARY.

1. Rinderpest in Nigeria has been studied with a view to differentiating the lung lesion in this condition from other specific pneumonias.

2. It has been shown that :—

(*a*) Goats may be infected with Rinderpest by inoculation with bovine virulent blood.

(*b*) Goat virulent blood produces Rinderpest in bovines and other goats.

(*c*) Goats may be infected by contact with reacting goats.

(*d*) Goats and bovines may be infected by goat blood from contact infection.

(*e*) Goats and bovines may be infected by bovine blood infected with goat strain.

(*f*) Goats may be infected by contact with infective bovines.

(*g*) Bovines may be infected by contact with infective goats.

Further work has been done with the double-inoculation of goats with bovine blood and bovine anti-rinderpest serum, and vaccination with bovine spleen vaccine.

Differentiation of this disease from contagious pleuro-pneumonia, by contact infection of known Rinderpest immune goats with the latter disease, occupied much time also.

Third of U. S. Practically Free from Bovine Tuberculosis.—(*Journal of the American Veterinary Medical Association*, New Series, Vol. 30, No. 5, November 1930.)

More than one-third of all the counties in the United States are now practically free from bovine tuberculosis, the U. S. Department of Agriculture announced the past month. On October 1, there were 1,035 counties classified as "modified accredited areas". A high mark in this work was reached in September, when 24 counties were added to the modified accredited area. These counties were located in nine states and included a total of 432,163 cattle. Twelve of the counties were in Ohio, where very rapid progress recently has been made in the campaign.

The Control of Warble Flies in North Wales.—W. MALDWYN DAVIES, B.Sc., PH.D., Adviser in Agricultural Zoology, University College of North Wales, Bangor. (*Journal of the Ministry of Agriculture*, Vol. XXXVII, No. 9, December 1930.)

SUMMARY OF RESULTS.

The bulk of the derris powder sold to farmers in North Wales during 1930 was supplied from four different sources; powder from these sources was used in the trials along with two proprietary washes. When it was used as a wash, derris powder from three of the sources proved highly toxic to warble-fly larvæ under critical, general and ordinary farm conditions. Derris powder from the remaining source, while yielding a moderately high percentage, kill under the critical tests which ensured sufficient solution entering each warble hole, failed to produce an effective kill under general and ordinary farm conditions. The writer is pleased to add that, in the case of the latter powder, the firm concerned, on being notified of these results, stated that no further supplies would be obtained from that source.

A solution which need only be diluted with water before application has, for obvious reasons, a distinct advantage over a powder, and it was hoped that a solution which was available would be

found effective. Unfortunately, the only wash available for these tests failed to give more than 75 per cent. kill under ordinary farm conditions. It was at first thought that the frothy nature of the wash on application prevented the entrance of the solution; but a second sample was received which had been prepared on a less frothy base and showed no greater efficiency.

Cost of Application.

Derris powder, highly toxic to warble-fly larvæ, was obtained last season at a retail price of 3*s.* per lb. This was sufficient to make 1 gallon of wash. The number of cattle that can be treated with 1 gallon of wash obviously varies with the degree of infestation with warbles, the care taken in application, etc. In the general tests (Division 2) above, with a heavy infestation, 1 gallon was sufficient to dress 50-60 cattle once. This was the initial dressing and naturally less wash would be required at subsequent dressings.

It is estimated, from the work in the Demonstration Scheme where small herds were involved, that 1 lb. of derris powder is sufficient to provide wash for four-monthly dressings on a farm with 20-25 infested cattle. On this basis, the cost for four-monthly treatments should not exceed 2 *d.* per animal.

Discussion.

From the preceding trials, it is evident that the farmer has at his disposal materials which, with ordinary care, are highly efficient in the destruction of warble-fly larvæ when applied under ordinary farm conditions. Derris powder wash is particularly suitable for this purpose, but, whereas most of the derris available to the farmers is highly toxic, the farmer must beware lest he obtains derris which is valueless for the destruction of warbles. Although, last season, few firms could give a guarantee of toxicity it should be possible in future to obtain such guarantee provided the firm can state that the derris was obtained from the same source or that it has been subsequently tested.

With the existence of an efficient and inexpensive insecticide, the control of the warble-fly now depends very largely upon the co-operation of farmers in organized anti-warble-fly campaigns. The advantage of treating cattle over large areas is obvious. During a period of agricultural depression, however, no additional expenditure upon insecticides will be undertaken unless prospects of a quick return are forthcoming. The farmer will receive the immediate benefit through the better condition of his treated cattle and he will also reduce the losses resulting from the "gadding" caused by the fly. The monetary value of these factors, unfortunately, is difficult to estimate, but several farmers who dressed their cattle for the first time this season have expressed the opinion that there was a decided improvement in the condition of the cattle after treatment. Further, there is evidence that the local butchers and dealers are fully alive to the situation and are prepared to pay 10 *s.* to 20 *s* more for a non-warbled beast. These factors should encourage farmers to join in an anti-warble-fly campaign.

Experiments on the Mechanical Transmission of West African Strains of *Trypanosoma Brucei* and *T. Gambiense* by *Glossina* and other Biting Flies.—A. W. Taylor, B. Sc., Entomologist, Tsetse Investigation, Northern Nigeria. (*Transactions of the Royal Society of Tropical Medicine and Hygiene,* Vol. XXIV, No. 3, 1930.)

Summary.

1. Four strains of *T. brucei* have been successfully transmitted by the direct method, using *G. tachinoides* as mechanical vector.

2. Direct transmissions of *T. brucei* by *G. tachinoides* have only been carried out where the interval between the break in the infecting feed and the resumption of the flies' meal on a clear animal does not exceed ten minutes.

3. Successful transmission has been effected by as few as four infecting bites.

4. Direct transmissions of *T. brucei* by the agency of *G. tachinoides* have only proved successful where the average number of trypanosomes in the peripheral blood of the infected animal exceeds one in five microscopic fields.

5. Some difference appears to exist in the direct transmissibility of the three strains of *T. brucei* used.

6. Negative results have been obtained in each of fifteen direct transmission experiments in which attempts were made to transmit six strains of *T. gambiense* by the agency of *G. tachinoides*.

7. *T. brucei* has been successfully transmitted by *S. calcitrans* by the direct method.

8. Experiments in which attempts have been made to employ *A. costalis, A. funestus, Aëdes vitatus*, and *Lyperosia* (sp?) as mechanical vectors of *T. brucei* have failed to effect transmissions.

9. Dissection and examination of the proboscis of *G. tachinoides* at intervals after an infecting meal, reveals the fact that motile trypanosomes may survive in the proboscis for as long as three hours; and that the maximum number of trypanosomes contained in the proboscis immediately after an infecting meal is often very considerably in excess of 600 when trypanosomes are abundant in the peripheral blood of the infected animal.

10. A brief account is given of the behaviour of trypanosomes taken up during an infected blood meal in the proboscis and gut of *Stomoxys, A. costalis, A. funestus* and *Lyperosia*. In none of those flies do the trypanosomes survive in the proboscis as long, or in such large number, as in *G. tachinoides*.

The Nature of Milk Fever.—Professor J. Russell Greig, Ph.D., M.R.C.V.S., Director, Animal Diseases Research Institute, Moredun, Edinburgh. (Eleventh International Veterinary Congress, London, 1930.)

Summary.

(i) There is no difference between the calcium values in parturient cows and those in non-parturient cows and in bullocks.

(ii) The onset of milk secretion is accompanied by a transient but appreciable fall in the blood-calcium which returns to normal after the crisis of initiation of lactation is passed.

(iii) In milk fever there is invariably a pronounced fall in the blood-calcium (82 cases examined). The degree of severity of the symptoms bears a distinct relation to the calcium level in the blood. From a series of observations made in one case, before and during the attack, the fall in calcium appears to be abrupt; it is coincident with the onset and corresponds with the progressive severity of the symptoms.

(iv) In an examination of 81 cases of diseased conditions in cattle other than milk fever, none was found to present a hypocalcaemia in any way comparable to that which obtains in that disease.

(v) Inflation of the mammae of normal lactating ewes causes a rise in the blood-calcium (about 10 per cent.).

(vi) Inflation of the mammae of the cow in cases of milk fever results in a pronounced rise in the blood-calcium. The rise is at first rapid, and the case usually shows definite signs of recovery when a level of about 6 to 7 mgm. of calcium per cent. has been reached.

(vii) Injection of calcium gluconate (Sandoz) exclusive of other treatment, elicits specific curative response in milk fever.

(viii) The subcutaneous injection of calcium gluconate can abort the milk fever attack. Evidence is submitted that calcium injection immediately after calving and preferably, reinforced by a second injection about 24 hours later would prove a preventive treatment.

(ix) The effect on the blood-calcium concentration of the oral administration of massive repeated doses of vitamin D is discussed. The observations suggest that the disease may be prevented by this means by commencing a massive administration of vitamin D a few days before calving.

An important general principle governing the counteraction effects of the calcium controlling mechanism upon sudden alteration of the normal blood-calcium level appears to have emerged.

(x) The blood-calcium values of normal sheep were observed. It would appear that the normal variation of blood-calcium is greater in sheep than in cattle.

The association of acute hypocalcaemia with lambing sickness is determined and the identity of this disease with milk fever established.

The known curative effects of mammary inflation in lambing sickness are also correlated with a rise in the blood-calcium values. In one case the therapeutic effect of subcutaneous injection of calcium was tested: The treatment resulted in rapid recovery.

(xi) The calcium values of normal horses were found to be considerably higher than those of cattle and sheep. In an examination of two cases of transit tetany in mares a pronounced hypocalcaemia was found. In one case of transit tetany, mammary inflation, and in the other calcium injection, was followed by complete cure.

Conclusions.

I. *The essential cause of milk fever is an acute blood-calcium deficiency.*

II. *The specific curative action of mammary inflation consists in raising the blood-calcium values.*

These conclusions are based on the following considerations:—

(1) Milk fever is invariably associated with an acute hypocalcaemia.

(2) The more severe cases correspond with the lower calcium values.

(3) The fall in calcium is approximately coincident with the appearance of the symptoms.

(4) Tetany is a symptom in severe cases of milk fever and the occurrence of tetany is recognised as consequent upon pronounced hypocalcaemia.

(5) Mammary inflation raises the level of blood-calcium in a normal lactating animal.

(6) Mammary inflation elicits a marked rise in the level of blood-calcium in milk fever and cures the disease; the process of cure, as manifested in the disappearance of the symptoms, corresponds with the rise of the blood-calcium.

(7) Injection of calcium, exclusive of other treatment raises the blood-calcium concentration and cures the disease.

(8) Milk fever in cows, lambing sickness in ewes, and transit tetany in mares are all rapidly cured by mammary inflation and these are the only conditions in an examination of over 500 samples of blood in which an acute hypocalcaemia has been found.

We have received the following publication from the Ministry of Agriculture and Fisheries, London :—

RATIONS FOR LIVE STOCK, (Sixth Edition), by the late T. B. Wood, C.B.E., M.A.,. LL.D., F.I.C., F.R.S.; Revised by H. E. Woodman, M.A., Ph.D., D.Sc. Ministry of Agriculture and Fisheries Miscellaneous Publications, No. 32, pages 1-62, 1930. [To be obtained at the office of the Ministry of Agriculture and Fisheries, 10, Whitehall Place, London, S. W. 1.] Price 6*d*. net, post free.

ERRATUM

The Indian Journal of Veterinary Science and Animal Husbandry, Vol. I, Part I, Plate V, facing page 27. Delete " ♂ " occurring after '*Corizoneura longirostris*'.

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ORIGINAL ARTICLES

NITROGEN RECUPERATION IN THE SOILS OF THE BOMBAY PRESIDENCY, PART II.

BY

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(Received for publication on 5th August 1931.)

I. Introduction.

In the year 1925 a memoir was published with the title " Nitrogen Recuperation in the Soils of the Bombay Deccan, Part I". [Sahasrabuddhe and Daji, 1925.] In this publication after making a mention of the work of the various investigators on the recuperation of nitrogen by soils, details of experiments done on the soil of the Bombay Deccan were described. The experiments were conducted in the laboratory on the medium black soil of the Deccan, taken at the end of the hot weather, kept dry and then exposed to varying conditions of light, water and temperature. The results were summarised as given below :—

(1) When water is added to the soil within ten days a large quantity of nitrogen is fixed and this goes on increasing till about thirty-five days and then slowly begins to decrease.

(2) Up to 30 per cent. of water, the larger the quantity of the water, the higher is the nitrogen fixed.

(3) The fixation of nitrogen and nitrification are higher at 40°C. than at lower temperature.

(4) Increase in nitrogen takes place both in the presence and absence of light.

(5) The addition of lime to the soil (already containing enough of lime) does not show any advantage over the original soil in increasing nitrogen fixation, but it facilitates nitrification.

(6) If the soil which has fixed the highest quantity of nitrogen after being moistened, gets dried up and then gets moistened again, the nitrogen increases further for four or five weeks more and then begins to go down. Repeated drying, however, does not increase the nitrogen contents beyond a certain limit.

(7) If the soil is heated to 100°C. it loses a small quantity of nitrogen. This, however, is soon made up, if enough water is added to it, and the total amount of nitrogen fixed in the heated soil is found to be higher than that in the unheated soil.

This paper which forms Part II, is only a continuation of Part I. It gives the results of experiments done with different typical soils of the Bombay Presidency. It also records the results of experiments done to find out the effect on nitrogen recuperation of added (*a*) lime as calcium carbonate, (*b*) phosphatic substances, (*c*) organic matter and (*d*) alkali salts.

The soils alone or with additional substances were kept at 35°C. in an incubator. It has been shown in Part I that the higher the temperature the higher is the nitrogen recuperation up to 40°C. This temperature is a little higher than the temperature to which soils in the Bombay Deccan are raised. The records (Manjri Dry Farm) show that the highest daily temperatures of soils during the hot season vary from 30°C. to 37°C. and it was hence that during all the experiments soils were maintained at the constant temperature of 35°C.

It was also observed in Part I that for medium black soil the higher the water contents up to 30 per cent. the higher was the recuperation. The water holding capacity of the medium black soil as mentioned further on (page 636) is 91·83 per cent. Thirty per cent. water is, therefore, nearly one-third the water holding capacity. In order to obtain comparative results it was necessary to have water with a fixed proportion to the water-holding capacity of the soils. All the soils had, therefore, water equal to one-third the water-holding capacity.

General plan of experiments.

About 1,000 grams of air-dry soil from the stock material were taken in a brass tray 20·5 cm. in diameter and 5·5 cm. in height. Nitrogen-free distilled water was added to the soil in the form of a thin spray to make up one-third of the water-holding capacity. The soil was slightly stirred and evenly mixed up with water. This formed the control pot. Similar trays with the same quantity of the soil were taken up for different treatments. When soluble materials were to be added they were dissolved in water and the solution was added to the soil in the form of a spray and finally extra water was added to make up one-third the water-holding capacity In the case of insoluble substances the material was first thoroughly mixed with the soil and then water was added.

Before incubating the soil trays were weighed and every day water was added by spray to keep up the original moisture content. All the trays were carefully incubated at 35°C.

In the study of the recuperation of nitrogren the following determinations were made on the first day and on every 14th day for six weeks.

(1) Organic and ammonical nitrogen.

(2) Nitrite nitrogen.

(3) Nitrate nitrogen.

(4) Moisture (at 98°C. in a steam oven).

Methods of analysis used were the same as given in Appendix in Part I.

II. Soils used.

The soils used in the experiments represent important types. They differ from each other sufficiently to be classed separately. A short description and analytical figures of each are given below. They help in properly interpreting the results of the experiments.

Description of Soils.

Medium black soil :—It is derived from the Deccan trap. The sample experimented upon was collected near Poona. It had been under *bajri* or *jowar* for years without any leguminous crop and at least for fifteen years previous to the experiments it had not received any manure. It had never been irrigated.

Deccan River Silt :—This is also derived from the washing down of the decomposed Deccan trap. The place (near Poona) where the soil was collected is flooded once or twice every year during the rainy season. The land was never under cultivation. It is used in gardens to replace old soil and to fill earthen pots.

Goradu soil :—This is a typical sandy soil well known in Gujarat. It was collected at Nadiad. The plot was manured every year with about 1,000 lbs. of farmyard manure. Tobacco is the only crop grown on this plot so far.

Laterite soil :—This is derived from laterite rock. The soil used for experiments was collected from a field under garden crop near Belgaum. It was heavily manured.

TABLE I.

Chemical Composition.

----	Medium black soil	River silt soil	Goradu soil	Laterite soil
	Per cent.	Per cent.	Per cent.	Per cent.
Moisture (given off at 98°C.)	6·60	6·30	1·80	2·68
Loss on ignition (excluding moisture given off at 98°C.)	11·40	9·12	2·72	12·07
Organic matter	..	1·88	1·48	3·79

TABLE I—*contd.*

Chemical Composition—contd.

—	Medium black soil	River silt soil	Goradu soil	Laterite soil
	Per cent.	Per cent.	Per cent.	Per cent.
Sand (acid insoluble)	58·40	62·51	67·40	55·82
Iron oxide (Fe_2O_3)	11·90	10·72	4·00	15·20
Alumina (Al_2O_3)	6·50	10·76	1·46	14·34
Total lime (CaO)	4·73	1·05	1·85	0·41
Magnesia (MgO)	1·60	0·40	0·30	0·90
Potash (K_2O)	0·40	0·17	0·39	0·31
Phosphoric acid (P_2O_5)	0·07	0·089	0·21	0·16
Total nitrogen	0·048	0·086	0.076	0·159
Carbonate Lime (CaO)	4·45	0·73	1·32	0·25
Equal to calcium carbonate	7·96	1·30	2·36	0·44

TABLE II.

Water-soluble constituents.

—	Medium black soil	River silt soil	Goradu soil	Laterite soil
Total soluble salts	Per cent. 0·05	Per cent. 0·08	Per cent. 0·09	Per cent. 0·05
Containing :— Total carbonate	0·014	0·011	0·011	0·003
Sodium carbonate	*Nil*	*Nil*	*Nil*	*Nil*
Total chlorine	0·0035	0·007	0·0035	0·0035

The percentage of total soluble salts is small and there is no sodium carbonate in any of these soils.

The mechanical constituents as determined by the International Method are as given below :—

TABLE III.

Nomenclature of soil separates	Mean diameter of the soil particles in millimeter	Medium black soil	River silt soil	Goradu soil	Laterite soil
		Per cent.	Per cent.	Per cent.	Per cent.
Sand	2·0—0·2	5·22	4·71	4·48	4·62
Fine sand	0·2—0·02	9·04	35·97	67·25	11·68
Silt	0·02—0·006	14·50	17·50	12·00	11·59
Fine silt	0·006—0·002	17·00	11·00	4·50	18·50
Clay	Below 0·002	33·00	16·00	9·00	42·00

Comparative capillary power of the soils used varied as under. Readings were taken at many stages but only a few are given in the table.

TABLE IV.

Period	Medium black soil	River silt soil	Goradu soil	Laterite soil
After	cms.	cms.	cms.	cms.
1 hour	6·7	15·2	19·7	12·2
2 hours	8·5	20·3	26·6	16·8
6 hours	13·0	33·2	43·3	27·7
1 day	22·8	52·0	68·5	44·0
4 days	36·5	72·8	98·7	65·2
8 days	44·7	85·5	112 5	77·5

The "sticky point" [Keen and Coutts, 1928] and water-holding capacity of the soils gave the following figures :—

TABLE V.

Type of soil	Moisture at 'sticky' point	Water-holding capacity
	Per cent.	Per cent.
1. Medium black soil	57·73	91·83
2. River silt soil	43·59	69·99
3. Goradu soil	26·20	41·59
4. Laterite soil	42·88	68·19

pH value of the soils as determined by Potentiometer were found to be as follows :—

TABLE VI.

—	Medium black soil	River silt soil	Goradu soil	Laterite soil
pH value	8·35	8·18	8·22	5·99

III. EFFECT OF ADDITION OF LIME.

It is well-known that lime is one of the essential plant food constituents and it is observed that addition of lime to some soils has a beneficial effect on plant growth. Russell [1930] has shown that the gain in nitrogen is much influenced by the amount of calcium carbonate present in the soil. Brown [1911] observed that calcium carbonate increased the nitrifying and nitrogen fixing power of soils. Others [Waksman and Karunkar, 1924] have observed that the addition of calcium carbonate to the soils increased the nitrogen-fixing power of soils.

In Part I, it was observed that the addition of lime to the soil (already containing enough of lime) does not show any advantage over the original soil in increasing nitrogen fixation but it facilitates nitrification. In order to ascertain the effect of additional lime on soils with different percentages of original lime, experiments were done on Goradu soil from Nadiad, River silt from Poona and Laterite soil from Belgaum by adding 3 and 5 per cent. of calcium carbonate.

Water was made up to one-third of the water-holding capacity and the treated trays along with controls for each soil were incubated at 35°C.

TABLE VII.

Milligrams of total nitrogen per 100 grams of soil on oven-dry basis.

Soil	Calcium carbonate added	1st day	14th day	28th day	42nd day
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Goradu (control) . . .	*Nil*	77·92	82·88	81·91	80·73
„ with lime added .	3·00	75·58	78·11	82·37	81·69
„ „ .	5·00	74·04	76·18	78·57	80·76
River silt (control) . .	*Nil*	86·17	. . .	91·01	89·15
„ with lime added . .	3·00	83·58	91·37	91·69	84·05
„ „ .	5·00	81·86	93·58	91·04	90·31
Laterite (control) . . .	*Nil*	163·34	164·96	166·26	166·89
„ with lime added .	3·00	158·47	157·12	169·12	166·88
„ „ .	5·00	155·22	155·20	166·50	171·63

Taking all the soils experimented upon and taking the highest figures reached by each soil, in six weeks it is distinctly seen that the higher the percentage of lime in the soil the higher is its power of recuperating nitrogen as shown in the following table.

The calculation is done as under :—Goradu soil gave 77·92 milligrams of nitrogen on the first day and the highest point reached during the experimental period was 82·88 milligrams. This means 4·96 milligrams of increase or 6·36 per cent. over the original. All the figures in Table VIII are obtained in the same fashion.

TABLE VIII.

Soil	Lime as $CaCO_3$	pH value	Nitrogen fixed per 100 grams of soil over the original nitrogen
	Per cent.	Per cent.	Per cent.
Medium black soil	7·96	8·35	21·17*
Goradu soil	2·36	8·22	6·36
River silt soil	1·30	8·18	5·6
Laterite soil	0·44	5·99	2·17

*This figure is obtained from Table XIII for medium black soil control on page 641.

The experiments with additional lime to these soils, clearly bring out the fact, as shown in the table below, that the smaller the proportion of original lime in the soil the greater is the beneficial effect of additional lime in increasing the nitrogen recuperation power of the soil.

The figures for Table IX are obtained as under :—Taking Goradu soil to illustrate, we have in Table VIII an increase of nitrogen of 6·36 per cent. in the soil when no outside lime is added. When 3 per cent. lime is added we get an increase from 75·58 to 82·37 (Table VII), *i.e.*, an increase of 8·98 per cent. Therefore, the effect of additional lime is the difference between 8·98 and 6·36. This is equal to 2·62 which is the figure given under 3 per cent. lime added in Table IX. All the figures in Table IX are similarly calculated. This long calculation is necessary to show the exact effect of lime.

TABLE IX.

Soil	Original lime present as calcium carbonate	Milligrams of nitrogen fixed over that in the control	
		3 per cent. lime added	5 per cent. lime added
[Sahasrabuddhe and Daji, 1925]	Per cent.	Per cent.	Per cent.
Medium black soil	7·96	*Nil*	*Nil*
Goradu soil	2·36	2·62	2·71
River silt soil	1·30	4·09	8·70
Laterite soil	0·44	4·55	8·40

As shown in Part I, the Medium black soil which already contains a high proportion of lime is not benefited at all by additional lime while all the other soils are benefited. In Goradu soil with 2·36 per cent. of original lime, addition of 3 per cent. shows some increase in the power of recuperation but 5 per cent. addition does not show any distinct advantage over 3 per cent. because the addition of 3 per cent. is enough to make up the required proportion of lime and the extra 2 per cent. has, therefore, no effect.

It was pointed out in Part I [Sahasrabuddhe and Daji, 1925], that the addition of lime increased the nitrifying power of the soil. The same tendency was shown by the Goradu, River silt and Laterite soils, when treated with lime.

IV. Effect of Phosphatic Substances.

Phosphoric acid is one of the important plant food constituents. In a suitable form it is found to be beneficial to crops and to small organisms. The addition of phosphorus to a soil has been found to increase the amount of nitrogen fixed. Bear [1917] gives the following amount of nitrogen fixed with and without phosphorus.

Table X.

—	Without phosphorus Nitrogen fixed	With phosphorus Nitrogen fixed
	Milligrams	Milligrams
Soil without lime	0·3	2·0
Soil with lime 0·05 per cent.	0·6	4·6

Russell [1930] mentions that on clay pastures dressings of basic slag have been found to increase the nitrogen content of the soil. Four soils, namely, the Medium black, River silt, Goradu and Laterite were experimented upon to find the effect of phosphatic substances on the nitrogen recuperation power of soils. The phosphatic substances used were (1) di-potassium mono-hydrogen phosphate which is easily soluble in water and neutral in reaction, (2) superphosphate which contains soluble phosphate and is acid in reaction, and (3) tricalcic phosphate (pure chemical) which is very slightly soluble and slightly alkaline in reaction. Each of the substances was added in two portions to each of the four soils. The quantities were equal to 0·01 per cent. and 0·015 per cent. of phosphoric acid (P_2O_5) per 100 grams of soil on oven-dry basis. All the soils had water equal to one-third the water-holding capacity and all the samples were maintained at 35°C.

The first trial of phosphoric acid with regard to the nitrogen recuperation

power of the soil was made with 0·0075 per cent. and 0·01 per cent. of P_2O_5 in the form of superphosphate on four soils and the results obtained are given below :—

TABLE XI.

Milligrams of nitrogen per 100 grams of soil on oven-dry basis.

Soil	1st day	14th day	28th day	42nd day
	Total nitrogen			
Medium black soil (control)		60·29	61·57	62·45
,, with 0·0075 per cent. P_2O_5	51·54	54·22	64·21	60·30
,, ,, 0·01 per cent. P_2O_5		55·08	64·62	67·59
River silt (control)		...	91·01	89·15
,, with 0·0075 per cent. P_2O_5	86·17	94·92	105·44	91·22
,, ,, 0·01 per cent. P_2O_5		96·10	108·27	94·65
Laterite soil (control)		164·96	166·26	166·89
,, with 0·0075 per cent. P_2O_5	163·34	166·80	165·75	156·08
,, ,, 0·01 per cent. P_2O_5		169·90	170·74	158·74
Goradu soil (control)		82·88	81·91	80·73
,, with 0·0075 per cent. P_2O_5	77·92	85·94	79·80	81·10
,, ,, 0·01 per cent. P_2O_5		86·88	80·64	81·63

It is clear from the above table that if phosphoric acid, in the form of superphosphate, is added to soils, their nitrogen recuperation power is increased. In the quantities used, the larger quantity of phosphoric acid has a better effect than the smaller quantity. Actual percentage increase over the control in each soil is as given below :—

TABLE XII.

Percentage increase over the control.

	Medium black soil	River silt soil	Laterite soil	Goradu soil
Original P_2O_5	0·07	0·089	0·16	0·21
Soil with added 0·0075 per cent. P_2O_5	3·41	16·75	*Nil*	3·93
Soil with added 0·01 per cent. P_2O_5	9·97	20·03	2·36	5·13

The Laterite soil which is acidic is not expected to show any improvement with the addition of acid substances. The River silt has been much benefited. With other two soils the smaller the original P_2O_5 the better is the effect of additional P_2O_5.

All the four soils mentioned above were experimented upon with P_2O_5 in other forms.

Each soil was treated with 0·01 per cent. and 0·015 per cent. of P_2O_5 in the form of potassium phosphate and tricalcic phosphate. The results are given below :—

TABLE XIII.

Milligrams of total nitrogen in 100 grams of soil on oven-dry basis.

Soil	Added P_2O_5	1st day	14th day	28th day	42nd day
	Per cent.				
Medium black control	Nil		60·29	61·57	62·45
,, ,, with potassium phosphate	0·010		59·72	60·99	56·98
	0·015	51·54	67·40	59·40	58·25
,, ,, with tricalcic phosphate .	0·010		55·96	66·82	59·38
	0·015		55·56	68·90	61·61
River silt control	Nil		...	91·01	89·16
,, ,, with potassium phosphate .	0·010		96·80	80·64	80·21
	0·015	86·17	105·11	98·18	86·36
,, ,, with tricalcic phosphate .	0·010		91·89	106·33	91·18
	0·015		95·31	108·62	95·33
Laterite silt control	Nil		164·96	166·26	166·89
,, ,, with potassium phosphate	0·010		171·95	161·11	150·14
	0·015	163·31	172·34	163·91	151·33
,, ,, with tricalcic phosphate .	0·010		167·42	160·09	161·62
	0·015		175·26	163·76	161·93
Goradu control	Nil		82·88	81·91	80·73
,, with potassium phosphate .	0·010		80·44	84·07	80·77
	0·015	77·92	86·21	84·47	81·60
,, with tricalcic phosphate .	0·010		78·43	79·75	82·88
	0·015		84·17	79·92	81·96

These again point to the fact that addition of phosphoric acid increases nitrogen recuperation power of the soil and the higher the quantity added the higher is the increase. The percentage of increase over the control is shown by taking the highest figure reached in six weeks for 0·015 per cent. of phosphoric acid added to each soil.

TABLE XIV.

Percentage increase over the increase in the control.

Soil	Potassium phosphate 0·015 per cent. P_2O_5 added	Tri-calcic phosphate 0·015 per cent. P_2O_5 added
Medium black containing 0·07 per cent. original P_2O_5	9·61	12·51
River silt containing 0·089 per cent. original P_2O_5	16·40	20·44
Laterite containing 0·16 per cent. original P_2O_5	3·34	5·12
Goradu containing 0·21 per cent. original P_2O_5	4·31	1·66

The River silt responds very well to the addition of P_2O_5. The Medium black soil which contains a small proportion of P_2O_5 also responds to the addition of P_2O_5 but the other two soils which contain enough of P_2O_5, do not much respond. The tri-calcic phosphate on the whole shows a better effect than potassium phosphate.

Comparing P_2O_5 in the form of superphosphate with that of tri-calcic phosphate the comparative results are as given below :—

TABLE XV.

Percentage increase in nitrogen recuperation over the increase in the control.

Soil	Superphosphate 0·01 per cent. P_2O_5 added	Tri-calcic phosphate 0·01 per cent. P_2O_5 added
Medium black soil containing 0·07 per cent. original P_2O_5	9·98	8·48
River silt containing 0·089 per cent. original P_2O_5	20·03	17·78
Laterite containing 0·16 per cent. original P_2O_5	2·36	0·32
Goradu soil containing 0·21 per cent. original P_2O_5	5·13	*Nil*

Superphosphate seems to have the best effect but tri-talcic phosphate which is insoluble is next to superphosphate. Potassium phosphate, although soluble, shows very little effect especially in such low proportions as 0·010 per cent. With 0·015 per cent. it comes up sufficiently high but not quite as much as tri-calcic phosphate. The effect of superphosphate and tri-calcic phosphate may be partly due to the lime present in these, but the effect cannot be chiefly attributed to lime. The Medium black soil contains a good amount of original lime but a small quantity of P_2O_5 ; and it is more benefited than other soils which are poorer in lime and richer in P_2O_5.

V. Effect of addition of organic matter.

Organic matter is a very important constituent of the soil, especially in India where the exposure of the soils to the hot sun for a long period, is likely to remove a good amount of organic matter.

Nitrogen contents of the soils cannot increase by themselves. Russell [1927] says that increases are possible only when carbon is increased. He also mentions that Pleiffer and Blank did not get any beneficial effect by adding sugar. Hutchinson [1918] by the addition of sugar, straw, plant, roots, etc., and Joshi [1919] by the addition of glucose, cane sugar or filter paper have observed that the nitrogen contents of sand or soil may be appreciably increased. Joshi also shows that the nitrogen fixed in this way does not nitrify within four weeks. Allison [1927] observed that addition of straw, fresh stable manure had an adverse effect on nitrification in the soil for sometime.

In the experiments given below cane sugar was added to the soils as organic matter. As a practical measure addition of cane sugar to the soil is out of the question but for experimental work cane sugar was selected in order to avoid all the factors except soluble carbohydrate material The object was to see what effect was produced on different soils if the same quantities of soluble carbohydrates were added to them. And the simple answer to the question could be obtained by adding a simple substance like cane sugar.

Goradu, River silt and Laterite were the three soils selected for experiments. They contain different proportions of organic matter. Cane sugar was added in solution in two proportions—two per cent. and four per cent. Water was added to make up to one-third the water-holding capacity of each soil and all the samples were incubated at 35°C.

TABLE XVI.

Milligrams of total nitrogen per 100 grams of soil on oven-dry basis.

Soil	Original organic matter	Added sugar	1st day	14th day	28th day	42nd day
		Per cent.				
Goradu	1·48	*Nil*	77·92	82·88	81·91	80·73
Do.	1·48	2	75·18	96·82	91·84	90·40
Do.	1·48	4	74·11	96·00	94·96	95·95
River silt	1·88	*Nil*	86·17	..	91·01	89·15
Do.	1·88	2	84·46	94·80	104·65	96·50
Do.	1·88	4	82·76	94·84	104·76	95·77
Laterite	3·79	*Nil*	163·34	164·96	166·26	166·89
Do.	3·79	2	159·12	159·08	162·86	167·22
Do.	3·79	4	156·85	156·10	163·16	166·78

Addition of 2 per cent. sugar shows a beneficial effect in increasing nitrogen fixation power and a further addition of 2 per cent. shows a further small advantage with the three soils under experiment. If the highest figures reached in six weeks are taken the per cent. increases over the increase in the controls are as follows :—

TABLE XVII.

Percentage increases over the increase in the control.

	Goradu soil	River silt	Laterite
With 2 per cent. sugar	22·42	14·98	2·93
With 4 per cent. sugar	23.17	15·10	4·16
Original organic matter	1·48	1·88	3·79

The smaller the proportion of original organic matter the greater is the effect of added organic matter.

The effect of added sugar on the nitrification in the soils is deleterious at least for six weeks as will be seen from the following table :—

TABLE XVIII.

Milligrams of nitric nitrogen per 100 grams of soil on oven-dry basis.

Soil	Added sugar	1st day	14th day	28th day	42nd day
	Per cent.				
Goradu	*Nil*	1·65	2·73	3·33	3·22
Do.	2	0·60	0·38	0·39	0·24
Do.	4	0·64	0·42	0·37	0·20
River Silt . . .	*Nil*	0·94	—	4·13	5·26
Do.	2	0·94	0·37	0·34	0·20
Do.	4	0·94	0·33	0·43	0·23
Laterite . . .	*Nil*	1·02	4·10	5·80	6·25
Do.	2	1·02	0·17	0·13	0·17
Do.	4	1·02	0·12	0·16	0·17

VI.—EFFECT OF ALKALI SALTS.

There are several tracts in the Bombay Presidency where alkali salts are found in the soils. In some places the quantities of the alkali salts are so much that the soils produce but a very poor crop or sometimes none at all.

Greaves [1922] and his associates and also Singh [1918] have found that the alkali salts like the carbonate, the sulphate and the chloride of sodium in limited quantities, stimulate nitrogen fixation but beyond certain concentrations they become toxic. Much work has been done on this particular question but the results obtained are not in all cases exactly the same.

The most important of the alkali salts are the carbonate, the sulphate and the chloride of sodium. In the experimental work done these salts were separately tried in two proportions on the following soils. The soils contain very small quan-

c

tities of soluble salts and none of them showed any traces of sodium carbonate which is strongly alkaline.

TABLE XIX.

—	Total soluble salts. Percentage on oven-dry basis
Medium black soil	0·086
River silt soil	0·085
Goradu soil	0·092
Laterite soil	0·051

The Medium black soil was treated with sodium carbonate. The Goradu and the Laterite soils were treated with all the three alkali salts in the proportions given below :—

TABLE XX.

—	Total soluble salts. Percentage on oven-dry basis
Sodium carbonate	0·01
Do. do.	0·02
Sodium sulphate	0·02
Do. do.	0·04
Sodium chloride	0·03
Do. do.	0·06

After making up the necessary porportion of water the trays were incubated. The results were as follows :—

TABLE XXI.

Milligrams of total nitrogen in 100 grams of soil on oven-dry basis.

Soil	Quantity of salt	1st Day	14th day	28th day	42nd day
	Per cent.				
Medium black . . .	*Nil*	51·54	60·29	61·57	62·45
Medium black with sodium carbonate.	0·01		56·53	57·73	55·44
	0·02		56·38	57·60	53·96
Goradu	*Nil*	77·92	82·88	81·91	80·73
Goradu with sodium carbonate.	0·01		77·75	79·86	81·22
	0·02		79·56	80·04	79·93
Goradu with sodium sulphate.	0·02		78·54	79·75	81·36
	0·01		79·35	79·56	81·08
Goradu with sodium chloride.	0·03		78·92	78·39	81·05
	0·06		78·64	78·81	80·41
Laterite . . .	*Nil*	163·34	164·96	166·26	166·89
Laterite with sodium carbonate.	0·01		163·42	164·21	165·57
	0·02		163·95	163·48	163·64
Laterite with sodium sulphate.	0·02		165·11	161·93	166·74
	0·01		164·22	161·15	163·69
Laterite with sodium chloride.	0·03		163·75	164·64	168·33
	0·06		159·26	158·32	162·18

The effect of the alkali salts will be easily understood if the percentage variation *plus* or *minus* from the per cent. increase in the control is calculated as in the

following table. Only the highest figures obtained in six weeks are taken for calculation.

TABLE XXII.

Percentage variation from percentage increase of nitrogen in the control.

Soil	Sodium carbonate		Sodium sulphate		Sodium chloride	
	0·01 Per cent.	0·02 Per cent.	0·02 Per cent.	0·04 Per cent.	0·03 Per cent.	0·06 Per cent.
Medium black	—9·16	—10·0	—	—	—	—
Goradu	—2·13	—3·64	—1·95	—2·31	—2·35	—3·17
Laterite	—0·82	—1·80	—0·1	—1·64	—0·85	—2·88

From these figures it is clear that only sodium chloride in the proportion of 0·03 per cent. had no deleterious effect on Laterite soil but with this exception all the salts in both the proportions showed a deleterious effect on the soils in their nitrogen recuperation power. It is also clear that the higher the proportion of the salt, the greater is the effect. Out of the three salts, sodium carbonate had the worst and sodium chloride the least effect.

The greatest effect is produced on the Medium black soil which contains the highest percentage of lime while the Laterite which has the smallest proportion of lime and which is distinctly acidic as indicated by its pH value has the least deleterious effect.

TABLE XXIII.

Percentage variation from per cent. increase of nitrogen in the control.

Soil	Lime as $CaCO_3$ present originally in the soil	pH value.	Per cent. variation from per cent. increase of nitrogen in the control with 0·02 per cent. sodium carbonate
Medium black	7·96	8·35	—10·0
Goradu soil	2·36	8·22	—3·64
Laterite soil	0·44	5·99	—1·80

No effect of these salts favourable or unfavourable was produced on the nitrifying power of the soil.

The experiments with the River silt soil require separate mention because the results are not in all respects in the same direction as those of other soils. When the River silt soil was treated with the alkali salts the following results were obtained :—

TABLE XXIV.

Milligrams of total nitrogen per 100 grams of soil on oven-dry basis.

Soil	Quantity of salt per cent.	1st day	14th day	28th day	42nd day
River silt	*Nil*	86·17	..	91·01	89·15
„ with sodium carbonate	0·01		95·13	94·61	97·28
	0·02		94·07	92·93	98·22
„ with sodium sulphate	0·02	86·17	87·79	86·03	92·06
	0·04		90·79	88·44	86·82
„ with sodium chloride	0·03	86·17	95·02	97·85	95·40
	0·06		94·78	94·98	99·16

In the case of the River silt except with 0·04 per cent. sodium sulphate where practically no effect is produced, the addition of alkali salts instead of producing a deleterious effect has stimulated the soil to fix nitrogen as shown below :—

TABLE XXV.

Per cent. increase of nitrogen over the increase in the control.

Soil	Sodium carbonate		Sodium sulphate		Sodium chloride	
	0·01 per cent.	0·02 per cent.	0·02 per cent.	0·04 per cent.	0·03 per cent.	0·06 per cent.
River silt	6·98	7·92	1·15	—0·24	7·5	8·95

Sodium carbonate and sodium chloride have distinctly stimulated the River silt to fix nitrogen and the higher quantity has given greater stimulation. It means that the quantities of alkali salts added were not sufficient to produce a bad effect on the River silt. In these experiments the alkali salts did not show any effect on the nitrifying power of the soil.

SUMMARY OF CONCLUSION.

1. As regards the soils experimented upon, the higher the percentage of lime in the soil, the higher is the nitrogen recuperation power of the soil. The smaller the proportion of original lime in the soil the greater is the beneficial effect of additional lime upto a certain limit in increasing the nitrogen recuperation power of the soil.

2. Additional lime always increases nitrification.

3. When superphosphate is added to soil its nitrogen recuperation power is increased except in the case of Laterite soil which has an acidic reaction. In the quantities used the larger the quantity of superphosphate added the better is the effect.

4. Similar results are obtained by the addition of tri-calcic phosphate or potassium phosphate.

5. The smaller the quantity of original phosphoric acid in the soil the better is the effect of additional phosphoric acid.

6. Out of the three forms used in supplying phosphoric acid, superphosphate proved to be the best (except on acid soil), tri-calcic phosphate stands next but not much below the superphosphate. Potassium phosphate stands third.

7. Addition of 2 per cent. of soluble organic matter like sugar has a good effect on nitrogen recuperation of soil. Further addition in the case of the soils experimented upon does not show much advantage. The effect produced is higher with soils containing smaller quantities of original organic matter than with those containing larger quantities of original organic matter.

8. Addition of sugar has a deleterious effect on the nitrifying power of the soil at least for sometime.

9. The alkali salts—sodium carbonate, sodium sulphate and sodium chloride—when added to Medium black soil of the Deccan, Goradu and Laterite soils show a deleterious effect on the nitrogen recuperation power of these soils. Sodium carbonate is the most and sodium chloride the least harmful of the three.

10. The alkali salts have the worst effect on the Medium black soil while their effect is the least on the Laterite which is an acidic soil.

11. The alkali salts with the quantities used in the experiments show a stimulating effect on the nitrogen recuperation power of the River silt soil.

12. The River silt which is a freshly deposited soil is easily stimulated by the addition of lime, phosphoric acid or organic matter and is also stimulated by the addition of small quantities of alkali salts in increasing its nitrogen recuperation power.

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PRELIMINARY WORK ON THE MANURING OF SUGARCANE IN NORTH BIHAR.

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INTRODUCTION.

Sugarcane is the most widely grown cash crop of North Bihar, and is yearly becoming of greater importance in the economy of the ryot; and for some years work on (*a*) the testing of new varieties for distribution, (*b*) better methods of cultivation and (*c*) manuring, has taken a leading place on the Departmental farms in the range. From (*a*) the Coimbatore varieties Co. 210 and Co. 213 have spread themselves over the range. From (*b*) the growing of the crop in lines, intercultivation through the hot weather and earthing during the monsoon with cheap bullock-drawn implements, have spread through the European factories and are gradually being adopted by the ryots. In (*c*) progress, though much slower, has now reached a definite stage.

It must be remembered that over the greater part of the tract, sugarcane is grown entirely without irrigation. The cane is planted shallow in February and early March, the land is beamed flat, and hoeings or intercultivations given at intervals through the hot weather to keep down weeds and conserve moisture till the monsoon. In certain areas where the soils are heavy and seem to dry out early, feeble irrigations are given in the hot weather, severely limited by the supply of water available and solely to keep the cane alive. Similarly supplies of farmyard manure are always inadequate and the cane gets generally a very small dressing. Where the land is a medium loam in really good condition yields of 600 to 800 maunds per acre are common but on most ryots' lands, owing to poor cultivation and inadequate manuring, the yields rarely exceed 300 maunds per acre.

EARLIER MANURIAL TRIALS.

Manurial trials on sugarcane were started tentatively in the North Bihar Range at the Sepaya Farm in 1925-26. It had been the custom for years to prepare the land for cane by green manuring with *Sanai* and by adding heavy dressings of cattle manure; also at first, small dressings of artificials were added to these preparatory applications for experimental purposes. The first trial in 1925-26 was to test the effect of extra nitrogen, and 80 lbs. 100 lbs. and 120 lbs. nitrogen per acre in the form of ammonium sulphate, was added to the basal dressing. The results (Table I) showed that the extra nitrogen had little effect and that what increase was obtained was not economic. But in the same year the effect of 80 lbs. P_2O_5 per acre added to the basal dressing, was tested against that of 80 lbs. nitrogen in ammonium sulphate; as a result it was found that the plots given super gave 11 per cent. more cane than those given ammonium sulphate, and the difference was statistically significant (Table II). In a third trial in the same year where super to give 80 lbs. P_2O_5 was added to 80 lbs. nitrogen in ammonium sulphate, both on top of the basal dressing, the addition of the P_2O_5 increased the yield by a statistically significant 10 per cent. (Table III). In both cases the increases were only 70 odd maunds of cane, but that was because the land having been well prepared and manured, the yields of control plots were high. The important point remained that even on such good land, P_2O_5 still gave an appreciable and constant increase.

The writer took over the range in the cold weather of 1926-27 and found that that season had been almost entirely wasted for this purpose because in the manurial trials small dressings of artificials had been added as top dressings on the richest and most heavily-manured cane land and of course gave little or no effect. But from other trials on rabi crops it was further made clear that this soil did respond to applications of P_2O_5 in a marked degree; and in one cane trial the substitution of 65 lbs. P_2O_5 for 40 lbs. nitrogen in a dressing of 80 lbs. nitrogen, gave a small but highly significant increase, though all the yields were very high (Table IV). It seemed clear that on this land phosphatic manures were likely to be more profitable than nitrogenous ones.

In 1927-28, therefore, only phosphatic manures were tested, no preliminary manures were given to the plots and sufficient replications and controls were included to give a high degree of significance. Unfortunately the writer, selecting a uniform plot, picked one also very rich, so that all the yields were very high and the effect of the manures was to a great extent masked. Even so (*vide* Table V) super to give 50 lbs. P_2O_5 per acre gave its usual 10 per cent. increase statistically significant, Guano at $3\frac{1}{2}$ maunds per acre, Ammophos to supply 38 lbs. nitrogen and 48 lbs. P_2O_5 gave only insignificant results.

Manurial trials on Sugarcane, Sepaya (Saran), 1925-26 and 1926-27.

Year, crop and place	Preparatory manuring	Manures tested	Number of re-plications and size of plots	Mean yield per plot maunds	Statistical treatment by student's short method. Ed.	Plots compared	Md./Ed.	Notes
			TABLE I.					
1925-26, Co. 213, Sepaya	Green manuring and farm-yard manure	Ammonium sulphate (1) 80 lbs. nitrogen per acre	6	51·5	1·6	1 and 2	0·2	
		(2) 100 „	·094 acre	51·8	..	1 and 3	2·1	
		(3) 120 „	..	54·8	..	2 and 3	1·9	
			TABLE II.					
1925-26, Co. 210, Sepaya	Green manuring and farm-yard manure	(1) Super 80 lbs. P_2O_5 per acre	6	53·4	1·7	1 and 2	3·2	80 lbs. P_2O_5 gave 11 per cent. more crop than 80 lbs. nitrogen.
		(2) Ammonium sulphate 80 lbs. nitrogen per acre	·072 acre	47·9	..	..	..	
			TABLE III.					
1925-26, Co. 210	Green manuring and farm-yard manure	(1) Ammonium sulphate Nitrogen 80 lbs. per acre + Super P_2O_5 80 lbs. per acre	6 ·072 acre	56·8 ..	1·7 ..	1 and 2 ..	3·1 ..	The addition of 80 lbs. P_2O_5 to the 100 lbs. nitrogen increased the crop by 10 per cent.
		2. Ammonium sulphate Nitrogen 80 lbs. per acre	..	51·6	..	..	..	
			TABLE IV.					
1926-27, Co. 210, Sepaya	Green manuring and farm-yard manure	1. Ammonium sulphate Nitrogen 40 lbs. per acre + Super P_2O_5 65 lbs. per acre	5 ·027 acre	31·5	·3	1 and 2	4·3	The substitution of 40 lbs. nitrogen by 65 lbs. P_2O_5 per acre increased the yields by 4 per cent. though the yields were very high.
		2. Ammonium sulphate Nitrogen 80 lbs. per acre	..	30·2	..	..	..	

Manurial Trials on Sugarcane Sepaya, Saran, 1927-28.

TABLE V.

Year, crop and place	Manures tested in lbs. per acre			Number of replications and size of plots	Mean yield per plot maunds	Statistical treatment by student's short method			Notes
	Kind	Nitrogen	P_2O_5			Ed.	Plots compared	Md./Ed.	
1927-28, Co. 210, Sepaya	1. No manure			9	21·4	·58	1 and 3 with 2	2·1	Although the land was very rich Super gave a 10 per cent. increase, Guano gave an increase also but decidedly less while Ammophos gave no significant increase.
	2. Super	0	40	2 ch.×9 ft.	22·6	..	..	..	
	3. No manure			$= \frac{3 \text{ acres}}{110}$	19·9	..	3 and 4	2·4	
	4. Guano			..	21·3	..	2 and 4	2·24	
	5. No manure			..	20·7	..	..	..	
	6. Ammophos	38 lbs.	50	..	21·5	..	..	..	

Accurate Trials on Representative Land in Different Parts of North Bihar.

By 1928-29 we had realised that most of our land was far richer than that used for cane in the districts, and we must therefore put our trials on the poorest uniform land we could find on the farm, that only small dressings of nitrogen seemed likely to be effective while the important application was phosphate, but that the best amount to use and the best time to apply it were doubtful. Also we had by now standardised the method of trial, using plots, 2 chains long and 5 rows wide, of which only the three centre ones were to be manured, the two side rows of each plot being border ones. Manures applied at planting were put in the furrows under the sets of the three centre rows. Those applied at earthing were spread in the right quantities in the four centre inter-row spaces of the plot, mixed into the soil with a cultivator, and thrown up to the rows of cane by the earthing. There were at least 6 repetitions of the whole series of treatments and unmanured control plots were scattered at frequent and regular intervals.

At Sepaya two decidedly elaborate trials were laid down—

(i) on *diara* land inside the farm, selected as of medium fertility and thought to be fairly uniform, and not manured except in the trial; and in this series plots

receiving farmyard manure at 270 maunds per acre ploughed in December for February planting, were included.

(ii) on high, light, poor land outside the farm, selected as being very poor but apparently uniform and healthy. The farmyard manure series had to be omitted from this series because the area of land available was insufficient.

The table below shows the arrangement of the plots, the dressings applied, the points it was hoped to bring out, and the mean yields per plot.

TABLE VI.

No.	Manures applied in lbs. per acre: At planting, N	At planting, P_2O_5	At earthing, N	At earthing, P_2O_5	Comparisons it was hoped to make	Mean yields per plot in seers. Average of 6 replications: Co. 210 on *diara* farm land	Co. 213 on poor high land
1	Farmyard manure at 270 maunds per acre in December					951	..
2	No manure		..	..	Standard dressing of Farmyard manure *Vs.* No manures *Vs.* 40 lbs. nitrogen & 50 lbs. P_2O_5	800	367
3	20	50	20	0		906	531
4	20	25	20	25	Effect of different times of application of the phosphate	886	548
5	20	0	20	50		891	557
6	No manure		..	..	No manure *Vs.* 40 lbs. N and 50 lbs. P_2O_5 *Vs.* 40 lbs. nitrogen and 100 lbs. P_2O_5	849	366
7	20	50	20	50		901	660
8	0	50	40	50	Effect of different times of applying nitrogen	890	616
9	0	50	60	50	Effect of different quantities of nitrogen	836	646
10	No manure		..	..	....	757	376

These two trials, both during their growing period and from final results, gave much important information. On the richer heavier *diara* land all yields were high and differences relatively small, *usar* patches developed during the season and yields were irregular and the probable error relatively high. The farmyard manure gave 139 maunds per acre stripped cane more than the no-manure plots, and this difference was highly significant $\left(\frac{\text{Md}}{\text{Ed.}} = 5{\cdot}1\right)$. Both 40 lbs. nitrogen and 50 lbs. P_2O_5 and 40 lbs. nitrogen and 100 lbs. P_2O_5 gave approximately the same increase, 90 maunds per acre, over the no-manure plots $\left(\frac{\text{Md}}{\text{Ed.}} = 3{\cdot}6\right)$ but the difference between the best yield from the 40·50 dressing and that from the farmyard manure was not significant. No significant differences could be detected on account of different times of applying the P_2O_5 or the nitrogen.

But on the poor, high, light land outside the farm very different results were observed. To begin with the effects of the manurial dressings compared with no manures were very obvious to the eye from August onwards and the greater benefit due to the heavier applications of phosphates was equally visible. On the unmanured plots the cane was even but poorly tillered, badly grown, yellow and unhealthy, heavily attacked by borer. The plots that received 40 lbs. nitrogen and 50 lbs. P_2O_5 were obviously better in every respect and those dressed with 40 lbs. nitrogen and 100 lbs. P_2O_5 were visibly better still. The final weighings confirmed these observations and gave further details. 40 lbs. nitrogen and 50 lbs. P_2O_5 gave a significant increase over no manure of 150 maunds per acre, $\left(\frac{\text{Md.}}{\text{Ed.}} = 8{\cdot}1\right)$. 40 lbs. nitrogen and 100 lbs. P_2O_5 gave an increase of 250 maunds per acre $\left(\frac{\text{Md.}}{\text{Ed.}} = 13{\cdot}6\right)$

The difference of 100 maunds between the results of these dressings was very significant $\left(\frac{\text{Md}}{\text{Ed.}} - 4{\cdot}8\right)$. Applying part of the nitrogen at planting and the rest at earthing as contrasted with applying it all at earthing gave an increase of 40 maunds per acre, just significant.

But differing times of applications of the phosphate made no difference nor did an increase in the nitrogen applied (Tables VII & VIII).

At the Sewan Farm in the same season a much simpler trial was carried through on Co. 210 cane on land lightly manured with cow-dung in which 20 lbs. nitrogen and 50 lbs. P_2O_5 at planting was tested against no manure and 20 lbs. nitrogen and 50 lbs. P_2O_5 at planting with a further 20 lbs. of nitrogen at earthing. For plan and detailed results see Table IX. 20 lbs. nitrogen and 50 lbs. P_2O_5 at planting gave a just significant increase of 62 maunds per acre over no manure and the addition of a further 20 lbs. nitrogen at earthing raised this increase to 132 maunds per acre.

Manurial trials on Sugarcane 1928-29 (Saran District).

Nature of trial and crop	Manures applied in lbs. per acre				No. of replications and size of plots 6 replications	Mean yield per plot	Statistical treatment by student's short method			Notes
	At planting		At earthing							
	N	P_2O_5	N	P_2O_5			Ed.	Plots compared	Md. - Ed.	
						TABLE VII.				
1928-29, Co. 210, Sewan										
1	No manure				..	17·9 mds.	·38	1 & 2	4·1	40 lbs. nitrogen and 50 lbs. P_2O_5 has given a very significant increase over no manure and a just significant one over 20 lbs. nitrogen and 50 lbs. P_2O_5.
2	20	50	20	..	Plots 2 chains × 9 feet.	21·5 ,,	..	2 & 4	2·2	
3	No manure				..	17·9 ,,	..	3 & 4	1·94	
4	20	50	..	..	..	19·6 ,,	..	..	..	
5	No manure				..	17·7 ,,	..	..	..	

Nature of trial and crop	Manures applied in lbs. per acre: At planting N	At planting P_2O_5	At earthing N	At earthing P_2O_5	No. of replications and size of plots 6 replications	Mean yield per plot	Statistical treatment by student's short method: Ed.	Plots compared	$\frac{Md.}{Ed.}$	Notes
						TABLE VIII.				
Sepaya Co. 210 cane on diara land										
1	Farmyard manure at 270 mds. per acre in December				..	951 seers	29·57	1 & 2	5·158	All the manurial dressings have given very significant increase over the "no manure", but the difference between the different dressings are not significant. The relative richness of the land made the heavier dressings of no more avail than the light ones, and its irregularity of fertility militated against the detection of differences due to the different times of application of the phosphate
2	No manure				6 replications plots 2 chains long by 3 rows 9 feet wide with two border rows per plot not included.	800 ,,	29·57	2 & 3	3·621	
3	20	50	20	0		906 ,,	29·57	..	..	
4	20	25	20	25		886 ,,	29·57	2 & 4	2·938	
5	20	0	20	50		891 ,,	31·83	5 & 6	2·828	
6	No manure					849 ,,	31·83	6 & 7	3·112	
7	20	50	20	50		901 ,,	31·83	..	..	
8	0	50	40	50	..	89[illegible] ,,	31·83	6 & 8	2·797	
9	0	50	60	50	..	836 ,,	..	..	..	
10	No manure				..	757 ,,	..	..	..	
						TABLE IX.				
Sepaya Co. 213 cane on poor high land										
1	No manure				..	367 seers	20·2	..	..	In this trial the land was poorer but more uniform and the differences due to the manures were very evident to the eye from August onwards. The differences due to all the manurial dressings were very large and very significant, while though dressings of 10lbs. nitrogen and 50 lbs. P_2O_5 gave increases of 150 mds. of cane per acre the addition of a further 5 lbs. per acre increased this difference to 250 mds. The time of application of phosphate, *i.e.*, whether applied early or late had no effect, but applying part of the nitrogen early increased the yield by 4[illegible] mds. per acre and chances are just over 30: 1 that this is real.
2	20	50	20	0	..	531 ,,	..	1 & 2	8·1	
3	20	25	20	25	..	548 ,,	..	1 & 3	9·[illegible]	
4	20	0	20	50	..	557 ,,	21·58	4 & 5	8·389	
5	No manure				..	366 ,,	21·58	4 & 6	1·773	
6	20	50	20	50	..	660 ,,	21·58	5 & 6	13·62	
7	0	5[illegible]	4[illegible]	50	..	616 ,,	20·86	6 & 8	2·109	
8	0	5[illegible]	60	50	..	646 ,,	..	..	..	

From the results of this season's trials it seemed clear that on the kind of land on which cane is generally grown by cultivators in North Bihar a dressing

of artificial manure containing between 40 lbs. nitrogen and 50 lbs. P_2O_5 and 40 lbs. nitrogen and 100 lbs. P_2O_5 was likely to be very profitable on cane.

The question of farmyard manure was postponed for the present as very inadequate dressings are available for use on cane by cultivators, and the question of time of application of the phosphate was further investigated at Sepaya. But the other farms in the range were utilised for a range manurial trial on sugarcane on the following plan, the trial being in every case on land not manured in its preparation for the cane crop.

Manures applied in lbs. per acre.

	At planting		At earthing		Total	
	N	P_2O_5	N	P_2O_5	N	P_2O_5
1	..	..	No manure	..	..	..
2	20	25	20	25	40	50
3	20	37·5	20	37·5	40	75
4	..	..	No manure	..	..	..
5	20	50	20	50	40	100
6	20	50	40	50	60	100

Plots were repeated in the same order at least 6 times and finished with an extra no-manure plot. The trials were all carried through according to the technique standardised in 1927-28, and as the results came in, they were treated statistically by student's short method and the results have been published in the annual reports of the farms concerned.

There are so far seven results of this trial available and except for the one already discussed as on poor high land at Sepaya all show much the same features.

1. In all the trials the dressing of 40 lbs. nitrogen and 50 lbs. P_2O_5 per acre, part at planting and part at earthing, has given a statistically significant increase of crop ranging from 66 maunds per acre on poor heavy land at Sewan in 1930-31 when, on account of drought, the stand of cane was so bad as to yield only 240 maunds per acre on the unmanured plots. to 253 maunds per acre at Darbhanga in the same year.

2. In no trial except the Sepaya one of 1928-29 has either 40 lbs. nitrogen and 75 lbs. P_2O_5 or 40 lbs. nitrogen and 100 lbs. P_2O_5 given an appreciable or significant increase over the 40 : 50 dressing.

3. In only one case, that of Darbhanga, 1929-30, has the dressing of 60 lbs. nitrogen and 100 lbs. P_2O_5 given a significantly better yield than the 40 lbs. nitrogen and 100 lbs. P_2O_5.

North Bihar Range.

Year	Place	Cane	Mean yields in Mds. per plot (132′ × 9′) from each treatment — Manures applied in lbs. per acre: No Manure	N P_2O_5 40 50	N P_2O_5 40 75	No Manure	N P_2O_5 40 100	N P_2O_5 60 100	No. of replications	Ed.	Remarks
				TABLE X.							
1929-30	Sewan .	21[illegible]	16·4	19·4	19·9	16·8	18·8	19·1	5	·63	40 : 50 gives significant increase $\frac{Md.}{Ed.}$ 4·7.
				TABLE XI.							
Do. .	Darbhanga	213	14·14	20·42	20·42	14·60	19·99	22·63	7	·70	40 : 50 gives significant increase $\frac{Md.}{Ed.}$ 9·0. 60 : 100 significantly better than 40 : 100 $\frac{Md.}{Ed.}$ = 3·8.
				TABLE XII.							
Do. .	Purnea .	213	18·83	21·19	22·13	20·26	20·22	21·79	6	1·03	40 : 50 gives significant increase $\frac{Md.}{Ed.}$ 2·3.
				TABLE XIII.							
1930-31	Sepaya .	213	8·9	12·8	..	..	13·1	..	6	·6	40 : 50 gives significant increase $\frac{Md.}{Ed.}$ = 6·3.
Do. .	Do. .	213	..	..	..	10·8	13·0	14·1	6	·8	60 : 100 gives significant increase $\frac{Md.}{Ed.}$ = 4·1. This trial was in 2 series.
				TABLE XIV.							
Do. .	Sewan .	213	9·1	10·9	10·1	8·8	10·9	11·4	5	·5	Owing to lack of moisture in hot weather on this heavy land stands very irregular 40 : 50 gave significant increase $\frac{Md.}{Ed.}$ = 3.
				TABLE XV.							
Do. .	Darbhanga	213	9·0	15·9	16·4	8·0	17·8	19·6	5	2·9	40 : 50 gave significant increase $\frac{Md.}{Ed.}$ 2·8.
				TABLE XVI.							
Do. .	Byreah Champaran	213	17·6	22·9	21·6	17·3	24·0	24·0	8	1·13	40 : 50 gave significant increase $\frac{Md.}{Ed.}$ 4·7.

DEFINITE RESULTS.

In all ten trials, ranging over North Bihar through the three seasons 1928-29 to 1930-31, the dressing of 40 lbs. nitrogen and 50 lbs. P_2O_5 has given a substantial and significant increase of cane crop in every case ; but in only 2 cases have any of the other dressings tried improved on this. From these ten trials, I have extracted the figures giving the yields of the no manure plots and of those dressed with 40 lbs. nitrogen and 50 lbs. P_2O_5 per acre, which were in every case alongside one another, and combined them in Table XVII with details of the location of the trial, the kind of cane used, the kind of land and the season. The increases in crop are shown both in maunds per acre and as percentages of the unmanured yields, and the degree of significance has been shown by the ratio $\frac{\text{Mean difference}}{\text{Error of difference}}$, in which a ratio of 2·1 means a 30:1 chance that the difference is due to the treatment,

TABLE XVII.

Showing the effects of a dressing of 40 lbs. nitrogen and 50 lbs. P_2O_5 per acre on sugarcane in North Bihar from 1928 to 1931.

Year	Place	Kind of soil	Season	Size and shape of plots	No. of repetitions	Yields per plot in mds. No manure	Yields per plot in mds. Manured with 40 lbs. N. 50 lbs. P_2O_5 per acre	Increase per acre	Percentage increase	Ed.	Md./Ed.
1. 1928-29	Sepaya Co. 210	Diara rich loam.	Fair .	132′ × 9′	6	20·0	22·6	95· mds.	13·2	·57	4·6
2. do. .	Do. Co. 213	Poor light high land.	Do. .	Do. .	6	9·2	13·3	150 „	45	·45	9·1
3. do. .	Sewan Co. 210	Heavy fairly rich.	Good .	Do. .	6	17·9	21·5	132 „	20	·75	4·8
4. 1929-30	Do. Co. 213	Heavy poor .	Fairly good.	Do. .	5	16·4	19·4	110 „	18	·51	5·9
5. do. .	Darbhanga 213	Medium loam poor.	Good .	Do. .	[illegible]	14·1	20·4	231 „	44	·43	14·7
6. do. .	Purnea Co. 213	Medium loam very rich.	Do. .	Do. .	6	18·8	21·2	88 „	13	·73	3·3
7. 1930-31	Sepaya Co. 213	Light high land rather *usar*.	Very bad short monsoon.	Do. .	6	8·9	12·8	143 „	44	·59	6·6
8. do. .	Sewan Co. 213	Heavy very poor.	Very bad stand of cane very poor.	Do. .	5	9·1	10·9	66 „	20	·44	4·1
9. do. .	Darbhanga 213.	Ditto .	Fairly good.	Do. .	5	9·0	15·9	253 „	77	1·58	4·4
10. do. .	Byreah . .	Medium loam rich.	Good .	Do. .	8	17·6	22·9	195 „	30	·59	9·0
								1,463			
							Mean	146 maunds per acre.			

The small difference at Sewan in 1930-31 has already been explained by the very irregular stand through all the plots due to lack of moisture in the hot weather on heavy soil. At Purnea the land was very rich and the soil does differ in important respects from that of the western districts of the range. Darbhanga shows a high increase in both years the trial was conducted there, while at Byreah in Champaran district, in the only trial so far completed the increase is also very high.

The mean of the 10 increases is 146 maunds per acre, 5 are above this and 5 below of which 2 are definitely abnormal. We are justified in concluding that on average cultivator's land, a dressing of 40 lbs. nitrogen and 50 lbs. phosphoric acid applied in 2 doses to the cane, half at planting and half at earthing will give an increase of crop of about 146 maunds per acre, most probably more.

Recommendations.

In all our trials we have used the various artificial manures entirely according to convenience in obtaining them, some times mixtures of ammonium sulphate and superphosphate, sometimes ammophos—16 per cent., nitrogen 20 per cent., P_2O_5—diammonphos—20 per cent., N 50 per cent.. P_2O_5—or leunophos - 20 per cent.. N 20 per cent., P_2O_5. No differences from the use of the different ones have so far appeared. For convenience of working in that only one manure need be purchased and handled in the field, we can at this stage safely recommend for cane either 3 maunds per acre of ammophos (16:20) or $3\frac{1}{2}$ maunds per acre Niciphos No. II. whichever is cheaper or more conveniently obtainable. Half the amount should be applied at planting and half at earthing.

The next stage.

Large numbers of cultivators use cattle-dung in varying quantities on their cane. Planters practise green manuring on a considerable scale. There are now-a-days available large quantities of very cheap oil-cakes. There is no doubt as to the value of the first two as adding humus as well as plant food to the soil. Whether the third is of any serious value except as a plant food is doubtful. But all three add to the soil less P_2O_5 than nitrogen, whereas our work seems to show the reverse to be required. Our future work therefore is being directed to trying to discover what supplement in the way of extra P_2O_5 is required with those three manures and whether additional nitrogen will also be profitable.

INHERITANCE OF AWN COLOUR IN WHEAT.

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Introduction.

In wheats the awn colours are black, red or white. The intensity of colour varies in each group. Black awns may be deep-black or merely sooty in appearance. The red-awned group may embrace various shades of brown or red, and the white-awned group may include yellow or yellowish-white.

The three major awn colours are found wherever wheat is grown. Percival [1921] finds black awns commonly occurring in *T. turgidum* and in *T. durum*, but rare in *T. vulgare*.

The colour in awns is greatly affected by climatic conditions. Certain black-awned wheats develop pigment in hot seasons only; damp and cool conditions suppress colour formation. In some wheats, however, black awn colour remains constant under varying climatic conditions, Percival [1921].

Previous Investigations.

Very little work has been reported on the heredity of awn colour in wheat. This is probably due to the fact that complications are introduced by climatic conditions.

The Howards [1913] made a cross between a black and a white-awned wheat and obtained in F_2 466 black and 135 white-awned plants. The numbers show a mono-hybrid inheritance.

Percival [1921] opines that awn colours follow the same type of inheritance as that of glumes. Both black and red being dominant to white, and black dominant to red.

Material and Methods.*

The investigation reported in this paper was carried at the Wheat Breeding Station, Kirkee, near Poona. Both the parents used in crosses are pure strains, maintained such for a number of years. These were isolated from wheats obtained from the Nasik district.

The female parent Kala-khapli 568 (*T. dicoccum*) has black awns and is very resistant to the rust, *Puccinia graminis tritici.*

The red-awned male parent Bansi 103 (*T. durum*) is a late, high-yielding selection, but extremely susceptible to the black stem rust. To obtain Bansi-like rust resistant strains crosses between these two strains were made in the season of 1925-26. Incidentally other characters were studied, awn colour being one of them.

The F_1 plants were grown in pots during the 1926-27 season, and three successful crosses were obtained. The black awn colour was found to be dominant to red.

The three crosses were designated H6, H7 and H8. The first yielded 74 grains and the other two 72 grains each. All of these were planted four inches apart in twentyfour-foot rows in the season of 1927-28. Due to the attack of *Fusarium* and *Rhizoctonia*, many plants died in the seedling stage and in all only 149 plants were obtained in F_2.

The F_3 generations were obtained in 1928-29. From each F_2 plant 146 seeds were planted four inches apart in rows.

The awn colours were noted in the field and again in the laboratory. Both the black and red awns have various shades, but variations when unaffected by atmospheric conditions are distinct enough to be classed as either black or red. The complete linkage of pubescent glumes and black awns, however, facilitated separation of black awns from red. The white awns, which appeard in F_2 were distinct and were easy to classify.

Goodness of Fit has been worked out according to Fisher [1928]. In his table Fisher has given values of X^2 corresponding to specially selected values of P. "If P is between ·1 and ·9 there is no reason to suspect the hypothesis tested." However, if P is below ·05 then the higher value of X^2 indicates a significant departure from hypothesis.

Results.

F_1 Generation.

The F_1 generation of the cross ♀ Kala-khapli 568 × ♂ Bansi 103 was like the female parent; black awn colour being dominant to red.

*The work was carried under the supervision of the following successive Crop Botanists to the Government of Bombay; Mr. R. K, Bhide, until 1927, Mr. S. G. Bhalerao, B.Ag., from 1927 to 1929; and Mr. R. K. Kulkarni, B.Ag., 1929-30. The present senior author has been in charge of the work since April 1930.

F_2 *Generation.*

In F_2 generation, besides the parental black and red awn colours, some plants were found to have white awns. The distribution of F_2 population was as follows :—

TABLE I.

Segregation of Awn colour in F_2.

Awn colour	Observed	Calculated 12 : 3 : 1	$\frac{(O-C)^2}{C}$
Black	107	111·7500	0·2019
Red	29	27·9375	0·0404
White	13	9·3125	1·4601
Total	149	149·0000	X^2 1·7024

P between ·30 and ·50.

On the basis of 12 : 3 : 1 ratio the observed data closely fit the expected ones.

F_3 *Generation.*

Behaviour of F_2 black-awned plants :—The behaviour of F_2 in F_3 generation was quite diverse. Out of the 32 black-awned plants ten bred true to character. Six of the plants segregated into black and red awns as follows :—

TABLE II.

F_2 Black-awned plants splitting into black and red-awned plants in F_3.

Culture No.	Observed		Calculated. 3 : 1		Total.	$\frac{D.}{*P.E.}$
	Black	Red	Black	Red		
6—4	53	21	55·50	18·50	74	$\frac{2·59}{2·51}=0·99$
6—61	75	24	74·25	24·75	99	$\frac{0·75}{2·90}=0·26$
6—62	64	23	65·25	21·75	87	$\frac{1·25}{2·72}=0·16$
6—65	60	18	58·50	19·50	78	$\frac{1·50}{2·57}=0·58$
6—70	24	4	21·00	7·00	28	$\frac{3·00}{1·54}=1·94$
8—64	59	27	64·50	21·50	86	$\frac{5·50}{2·70}=2·03$
Grand total	335	117	339·00	113·00	452	$\frac{4·00}{6·20}=0·64$

* The formula, ·6745 $\sqrt{p.\ q.\ n.}$ was used, where p is the percentage of individuals in one of the two classes, q is 1·0—p and n the total number of observations.

In almost all the cases the observed numbers are surprisingly close to expected ones. The last two cultures show somewhat large deviations. The odds against the occurrence of deviations as great or greater than these are 4 : 1 and 4·64 : 1 respectively. The grand totals of black and red awns deviate only by four from the calculated frequencies. The deviation is only ·61 times the probable error. Since black is throwing red coloured awns it must be dominant to red.

Ten of the F_2 black-awned plants segregated into black and white-awned plants as shown in the following table.

TABLE III.

F_2 Black-awned plants splitting into black and white-awned plants in F_3.

Culture No.	Observed		Calculated 3 : 1		Total	$\frac{D.}{P.E.}$
	Black	White	Black	White		
6—5	63	24	65·25	21·75	87	$\frac{2·25}{2·72}=0·83$
6—7	44	25	51·75	17·25	69	$\frac{7·75}{2·42}=3·10$
6—11	77	25	76·50	25·50	102	$\frac{0·50}{2·95}=0·17$
6—18	73	21	70·50	23·50	94	$\frac{2·50}{2·83}=0·88$
6—22	50	12	46·50	15·50	62	$\frac{3·50}{2·29}=1·52$
6—41	68	23	68·25	22·75	91	$\frac{1·75}{2·78}=0·63$
6—43	82	27	81·75	27·25	109	$\frac{0·25}{3·04}=0·08$
6—71	18	6	18·00	6·00	24	0 0
6—73	12	2	10·50	3·50	14	$\frac{1·50}{1·09}=1·37$
8—7	59	15	55·50	18·50	74	$\frac{3·50}{2·51}=1·39$
Grand total	546	180	544·50	181·50	726	$\frac{1·50}{7·86}=0·19$

With the conspicuous exception of culture 6-7; all the others give very close fits to calculated numbers. The deviation is 7·75, and 3·19 times the probable error, indicating the probable occurrence of a deviation as great or greater in only three out of a hundred trials. This is certainly a very poor fit. But examining the behaviour of other cultures it becomes at once apparent that some mechanical agent must be a disturbing factor in culture 6-7. It will be noted that the odd behaviour of culture 6-7 is mainly due to the shortage of black-awned plants. These may have died due to the attack of *Fusarium* and *Rhizoctonia* in the seedling stage.

The grand total of observed black and white-awned plants gives almost a perfect fit to expected numbers.

The remaining six black-awned plants gave progenies like that of the F_1 plants. The distribution of awn colour for each culture was as follows :--

TABLE IV.

F_2 Black-awned plants segregating into black, red and white-awned plants in F_3.

Culture No.	Observed.			Calculated. 12 : 3 : 1			Total	X^2	P Between
	Black	Red	White	Black	Red	White			
6—21	53	9	5	50·25	12·5625	4·1875	67	1·3180	·30 & ·50
6—24	18	8	3	21·75	5·4375	1·8125	29	2·6321	·20 & ·30
6—37	81	13	7	75·75	18·9375	6·3125	101	2·3008	·30 & ·50
6—39	74	11	5	67·50	16·8750	5·6250	90	2·7407	·20 & ·30
6—56	81	18	6	78·75	19·6875	6·5625	105	0·2571	·80 & ·90
6—66	73	9	5	65·25	16·3125	5·4375	87	4·2337	·10 & ·20
								ΣX^2 13·4824	·30 & ·50
Grand Total	380	68	31	359	90	30	479	6·6395	·02 & ·05

The value of P of individual cultures range between ·10 to ·90, indicating that the departures from expectation have no real significance. However, the X^2 value, 6·6395, of the grand total, gives a P below ·05, pointing to a probable discrepancy. This seems to be mainly due to the behaviour of culture 6—66 which has a large defficiency of red-awned plants.

However, when the X^2s are summed, the total, 13·4824, gives a value of P between ·30 and ·50 for 12 degrees of freedom, showing that all the cultures behave essentially the same.

Behaviour of F_2 red-awned plants in F_3.

Out of the ten red-awned plants four gave only red-awned progeny in F_3. The rest of the plants segregated into red and white-awned plants as shown in Table V.

Table V.

F_2 Red-awned plants segregating into red and white-awned plants in F_3.

Culture No.	Observed		Calculated 3 : 1		Total	D. / P.E.
	Red	White	Red	White		
6-15	50	25	56·25	18·75	75	$\frac{6·25}{2·52}$ = 2·48
6-30	34	14	36·00	12·00	48	$\frac{2·00}{2·02}$ = 0·99
6-31	52	21	54·75	18·25	73	$\frac{2·75}{2·49}$ = 1·10
6-46	61	18	59·25	19·75	79	$\frac{1·75}{2·59}$ = 0·67
6-47	70	27	72·75	24·25	97	$\frac{2·75}{2·87}$ = 0·96
7-35	12	4	12·00	4·00	16	.. ..
Grand Total	279	109	291·00	97·00	388	$\frac{12·00}{5·75}$

All the cultures show very close approximations to expectation, except the first one. The odds against the occurrence as great or greater than the deviation of 6-15 are 9·98 : 1. The grand totals of red and white-awned plants give a deviation of 12 with a probable error of 5·75. The odds against the occurrence as great or greater than the observed one are 5·38 : 1.

Behaviour of F_2 white-awned plants.

Only four F_2 white-awned plants were grown in F_3. All of these bred true. In subsequent generations white-awned plants were observed to breed true, indicating their recessive nature.

Genic Interpretation.

It is evident from the foregoing data that both black and red awn colours are dominant to white condition, and segregate in monogenic proportions. The black awn colour is also dominant to red, showing an epistatic behaviour. Further more, there are some F_2 black-awned plants which behave like the F_1, indicating identical genic constitution.

The white awns, which first appeared in the F_2 progeny, bred constant throughout. They are, therefore, recessive in constitution.

The genes for black and red awn colours are designated as B and R respectively. As both the parents are derived from pure lines, they should have homozygous constitution. The gene R can express itself only in the absence of the epistatic gene B. The red-awned Bansi 103, therefore must have bbRR genotype. The other parent Kala-khapli 568, must be carrying opposite allelomorphs of Bansi, as the cross between the two presents a double heterozygous behaviour in F_2. Moreover, it has been found that the gene R simultaneously causes red colouration of glumes and awns, while the action of gene B is confined to awns only. The Khapli parent has white glumes indicating the presence of the recessive allelomorphs of gene R. The genotype of Khapli would, therefore, be BBrr.

The F_1 will be hybrid for both characters and upon self-fertilization would yield the following genotypes in F_2, whose F_3 behaviour is also indicated.

Awn colour	F_2 Genotypes	Behaviour in F_3
12 Black . .	1 B B R R	Breeds true.
	2 B B R r	Breeds true.
	2 B b R R	3 Black : 1 red.
	4 B b R r	12 Black : 3 red : 1 white.
	1 B B r r	Breeds true.
	2 B b r r	3 Black : 1 white.
3 Red . .	1 b b R R	Breeds true.
	2 b b R r	3 Red : 1 white.
1 White . .	1 b b r r	Breeds constant.

The presence of gene B either in a single or double dose, causes black awn colour. The first six genotypes, give black-awned condition. Of these, three breed true in F_3; one each segregates into 3 black : 1 red, and 3 black : 1 white. The

double heterozygotes split in all the three colours in the proportion of 12 black : 3 red : 1 white.

There are only two genotypes, b b R R and b b R r which produce red awns; the latter breaks up in F_3 giving 3 red to 1 white.

The white, being a double recessive, breeds constant.

It will be seen from the data presented that the theoretical behaviour in F_2 and F_3 generations of the Kala-Khapli and Bansi cross has been entirely realized.

SUMMARY.

1. Data are presented which show that the black awn colour of Kala-Khapli 568 (*T. dicoccum*) and the red awn colour of Bansi 103 (*T. durum*) are caused by two separate genes.

2. The gene B produces black colour of awns and is epistatic to the gene R.

3. The gene R causes red awns.

4. The modification of the ordinary dihybrid ratio to 12 : 3 : 1 is caused by the epistatic behaviour of the gene B.

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CORRELATION BETWEEN FROST AND THE PRECEDING METEOROLOGICAL CONDITIONS.

BY

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(With 4 figures.)

[*Summary* : This paper is the first of a series on correlation between frost and the preceding local meteorological conditions in Northern India. Lahore 16 hours (local time) observation for the period 1915-29 have been analysed statistically in the paper, and equations are developed between the minimum temperature of the night and the dew-point, wet bulb and dry bulb temperatures at 16 hours in the preceding afternoon. The physical significance of these statistical equations is discussed. The observed and the calculated values of the minimum temperature agree closely in over 93 per cent. cases ; the discrepancies in the remaining 6 or 7 per cent. cases are not large and the causes producing them are explained. Most of the occasions on which the discrepancies are liable to occur can be foreseen and allowed for by a forecaster having the facilities of the Indian synoptic chart.

Pressure distributions most favourable for the occurrence of frost are discussed. On account of the importance of minimum temperature forecasts to agriculture, the need of regular afternoon observations of air temperature and humidity under standard conditions of exposure at all agricultural centres is stressed.]

1. Introduction.

Temperature is one of the most important elements in determining the growth of plants, agricultural crops and fruits. Very high and very low temperatures affect crops in various ways, principally by preventing germination, checking growth, killing all or part of the vegetative parts, injuring the blossoms or damaging the maturing products. Most plants make growth only during the portion of the year, when the temperature remains within certain limits, maturing, dying or becoming dormant when the temperature exceeds these limits. It is believed [Smith 1920], that 6°C or 42°·8 F marks the temperature below which most field and garden crops and plants will make little, if any, development ; most of the tender varieties of these are either killed or seriously damaged if the temperature falls below the freezing point (32°F) for any considerable time.

As a result of nocturnal radiation, the minimum temperature of the night generally occurs in the early morning shortly before sunrise. The problem of forecasting frost in India, therefore, is closely connected with the problem of forecasting the night minimum temperature. This paper is the first of a series to determine the correlation between the night minimum temperature at a station and the local meteorological conditions in the preceding afternoon.

2. An examination of the available meteorological data for the plains of India shows that the temperature of the air in the Stevenson screen (height 4′ above ground) rarely falls to or below the freezing point outside the region comprising Kashmir, the Northwest Frontier Province, Baluchistan, the Punjab, Rajputana, north Sind, Central India, the west Central Provinces, the United Provinces and the submontane districts of Bihar, Bengal and Assam. Regular afternoon meteorological observations were introduced at the 2nd and 3rd class observatories of the India Meteorological Department in northern India about the end of 1929. The records at these observatories are therefore not sufficiently long for the purposes of a statistical study. There are a few first class observatories, namely, Quetta, Peshawar, Srinagar, Agra, Jaipur and Lahore in the above mentioned region at some of which afternoon records for a sufficiently long period are available. The afternoon observations recorded at Lahore at 16 hours (local time) during the period 1920-29 are discussed here ; those for the other stations will be taken up separately.

Since frost occurs on clear nights, when radiation from the ground is strong ; only data for clear nights were considered. A night was taken as clear when the amount of cloud was zero (on the scale 0-10) at the time of the preceding 16 hours routine observations, and 8 hours routine observations on the succeeding morning. During the period under examination, there were 81 such nights available in December, 63 in January and 62 in February. As a result of preliminary statistical examination, it was found that the data for December and January could be combined ; these months are therefore considered together in section 4. To increase the number of observations for February, data for another five years, 1915-19, were included for this month alone, thereby raising the number of observations for this month to one hundred.

Monthly Frequency of Frost.

3. Frost occurs in northern India during the period November-March, but at stations like Srinagar, it may also occur in September and May. The percentage frequency and the mean number of days of frost per month (*i.e.*, when the minimum temperature fell below 32°F) at Lahore at 4 ft. above ground and at the surface for each month of this period are given in Table I. Similar information in respect of Srinagar, Peshawar, Rawalpindi and Dehra-Dun is also included in the table,

for comparison. Of the five stations given in the table, grass minimum temperatures are available for Lahore and Srinagar only.

TABLE I.

Percentage frequency and the mean number of days of frost at Lahore, Srinagar, Peshawar, Rawalpindi and Dehra-Dun, in each month of the period September-May at 4 ft. above ground and at the surface (where available).

Station	Height A. S. L.	September	October	November	December	January	February	March	April	May	Total number of days of frost	Period of Record
					4 ft. above ground.							
Lahore . .	ft. 702	..	..	..	*36*	*36*	28	..	..	..	14	1901-29
					(0·2)	(0·2)	(0·1)					
Srinagar . .	5201	..	0·0	19	*29*	27	21	3	0·1	..	1719	1901-20
			(0·5)	(16·5)	(24·7)	(23·5)	(18·1)	(2·7)	(0·1)			
Peshawar. .	1164	..	..	..	*48*	38	14	..	..	..	81	1901-20
					(1·9)	(1·5)	(0·5)					
Rawalpindi .	1674	..	..	1	43	*44*	12	..	..	..	115	1901-20
				(0·1)	(2·5)	(2·7)	(0·7)					
Dehra-Dun .	2239	..	..	..	..	40	*60*	..	..	..	5	1901-20
						(0·1)	(0·1)					
					At the Surface							
Lahore . .	702	..	..	12	34	*38*	15	1	..	..	819	1913-29
				(5·6)	(16·5)	(18·0)	(7·5)	(0·5)				
Srinagar . .	5201	1	10	18	18	*19*	17	12	4	1	2505	1913-28
		(1·3)	(15·6)	(28·3)	(28·7)	(30·1)	(25·9)	(19·1)	(6·7)	(1·0)		

NOTE.—Figures within brackets denote the mean number of days of frost per month.

Table I shows, as might be expected, that frost is most frequent in December and January, the coolest months of the year. At Lahore, Rawalpindi, Peshawar and Dehra-Dun, it occurs almost entirely during the period December-February. Freezing temperatures are less frequent at 4 ft. above ground than at the surface on account of the strong inversions of temperature which prevail in the surface layers of the atmosphere in the dry season from evening to early morning. For example in the cool season at Lahore, the minimum temperature* of the air recorded in the Stenvenson screen (*i.e.*, 4 ft. above ground) may be higher than the grass minimum temperature (bulb $\frac{1}{2}''$ above ground) by about 8 to 10°F. The magnitude of this difference in temperature varies with the locality depending upon the exposure of the instruments, the nature of the ground surface and the composition of the atmosphere with regard to water vapour, carbon dioxide, and suspensions.

* Memoirs, Ind. Met. Dept. Vol. XII, page 45.

4. Relation between the minimum temperature (N) on a clear night and the dew-point (P), dry bulb (D) and wet bulb (W), temperatures of the air at 16·00 hrs. (local time) in the preceding afternoon.

Dot charts were prepared separately for the period December-January and February showing the relation between :—

(a) the depression of the dew-point below the dry bulb temperature at 16·00 hrs. local time (*i.e.*, D—P) and the difference between the minimum temperature of the night and the dew-point at 16 hrs. in the preceding afternoon (*i.e.*, P—N), and

(b) the dew-point of the air at 16 hrs. (local time) and the difference between this dew-point and the minimum temperature of the following night (*i.e.*, P—N).

The dot charts are reproduced in Figs. 1 to 4 below.

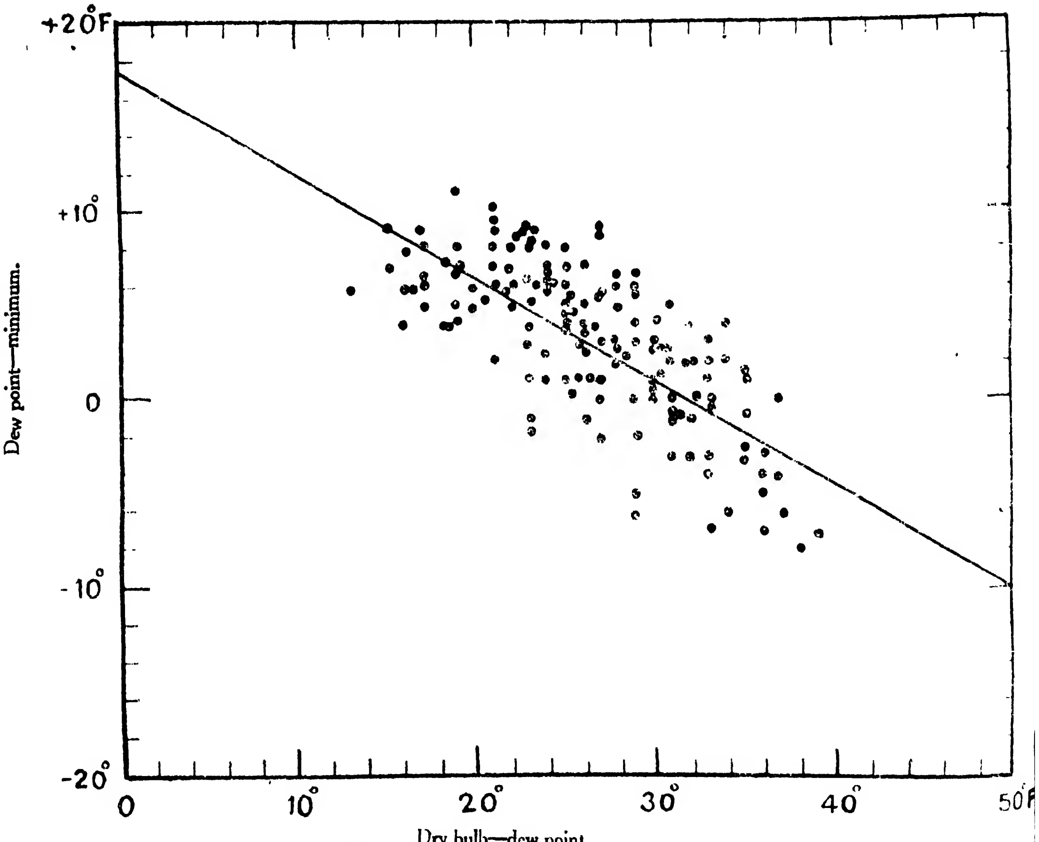

Fig. 1. Dot chart showing the relation between the dry bulb temperature minus the dew point at the evening observation (16 hrs. local time) and dew point minus minimum temperature at Lahore in Dec. & Jan. (1920—29).

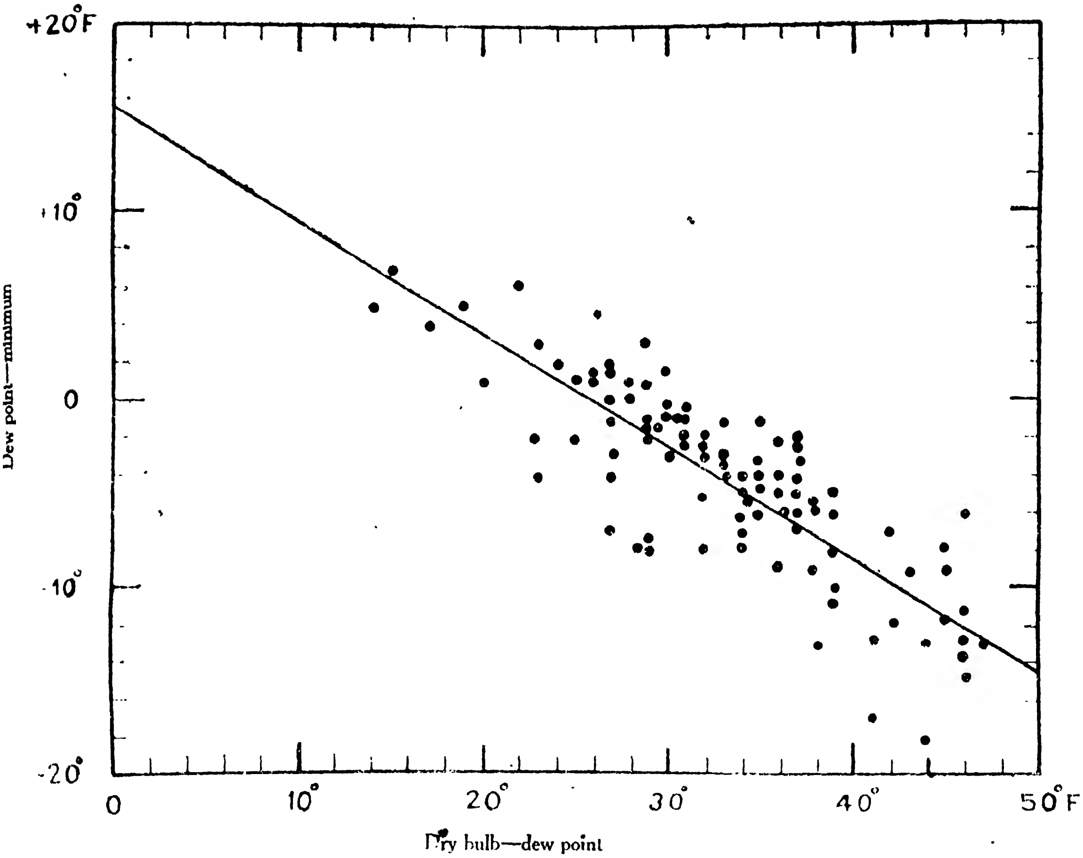

Fig. 2. Dot chart showing the relation between the dry bulb temperature minus dew point at the evening observation (16 hrs. local time) and dew point minus the minimum temperature at Lahore in February (1915—29).

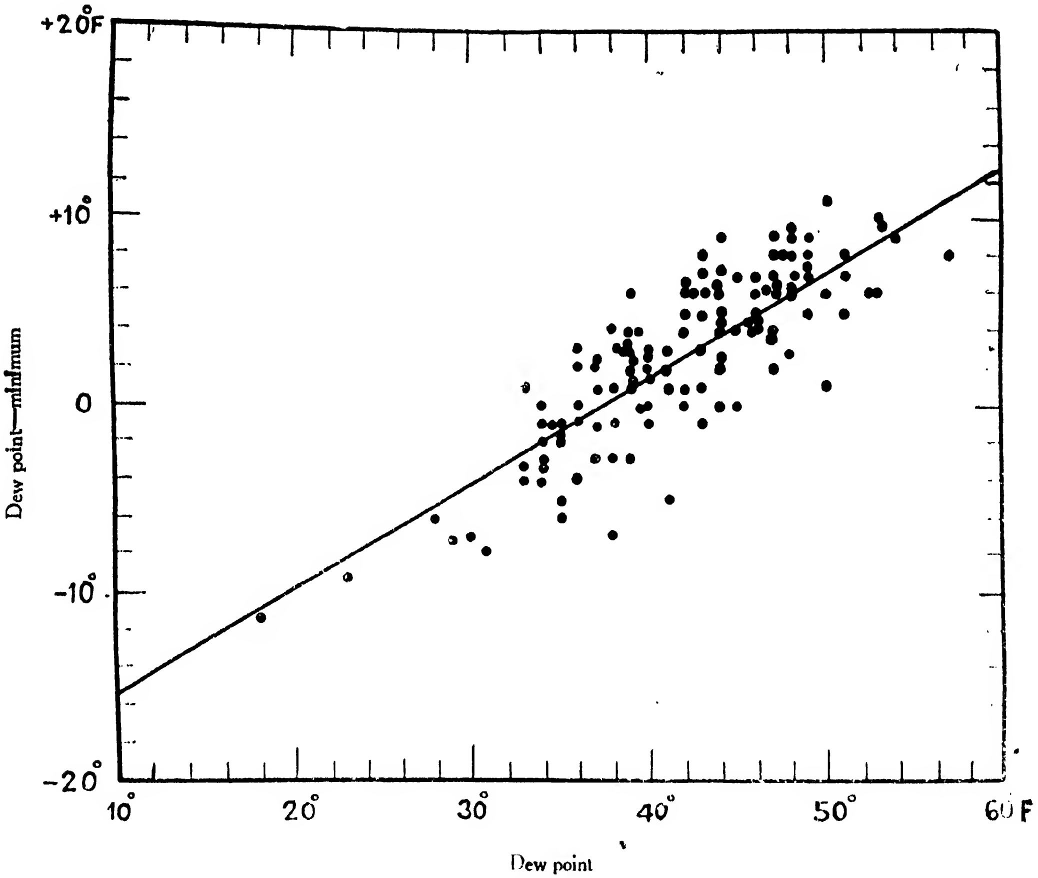

Fig. 3. Dot chart showing the relation between the evening dew point (16 hrs. local time) and dew point minus minimum temperature at Lahore in Dec. & Jan. (1920—29).

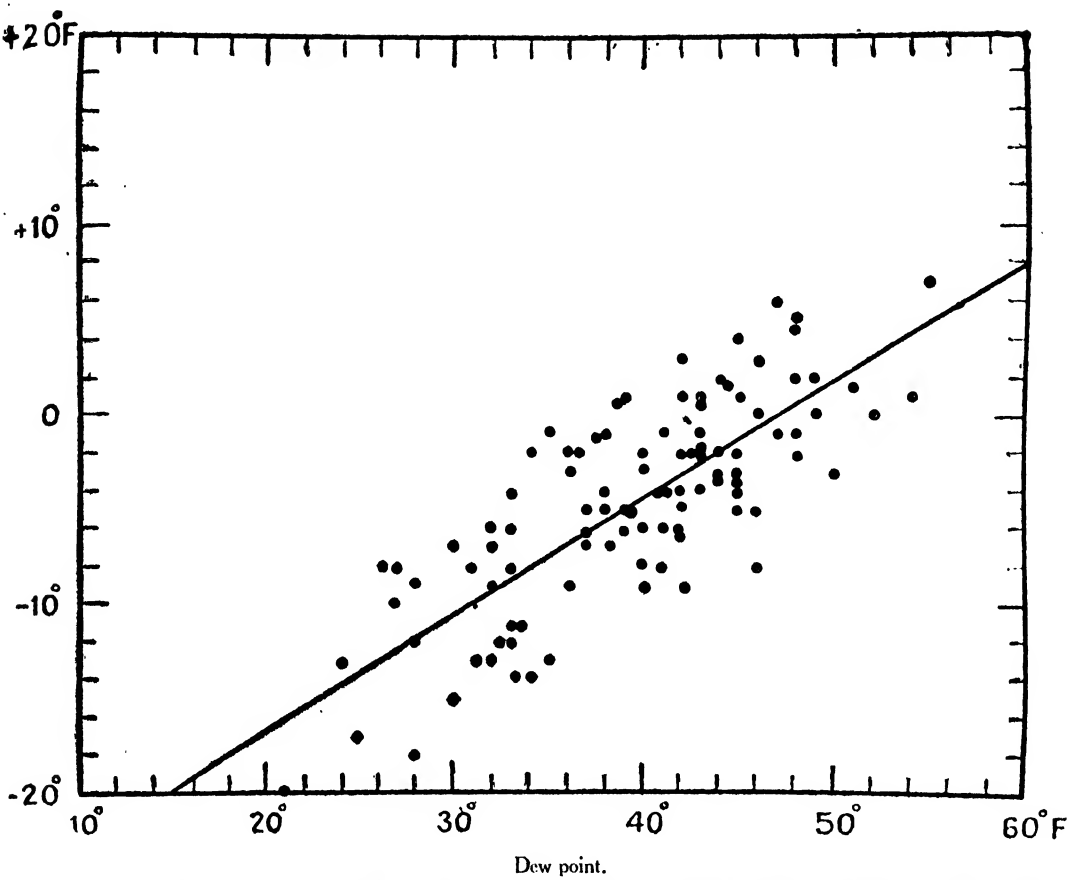

Fig. 4. Dot chart showing the relation between the evening dew point (16 hrs. local time) and dew point minus minimum temparature at Lahore in February (1915—29).

The charts show that the relation between the variables under reference is practically linear in each case. The continuous lines on the charts are the lines of best fit calculated by the method of least squares. The corresponding normal equations for the lines are :—

(1) December-January (1920-29); (dew-point —munimum) and (dry bulb —minimum), Fig. 1.

$$(P-N)=17{\cdot}3-0{\cdot}544\ (D-N) \qquad \text{(I)}$$

The scatter of the observed values of (P—N) about the line of best fit can be seen from the figure. Since P & D are known from the afternoon observations, the

value of N can be readily calculated from the above equation. The standard error of the estimate of N from this equation, *i.e.*

$$\sqrt{\frac{\Sigma(\text{observed value of N—calculated value of N})^2}{\text{total number of observations}}}$$

comes to 3·2°F.

(2) February (1915-29); (dew point —minimum) and (dry bulb —minimum), fig. 2.

$$(P—N)=15\cdot5—0\cdot604\ (D—N) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (ii)$$

The standard error of the estimate of N from this equation is 3·3°F.

(3) December-January (1920-29), (dew point —minimum) and dew-point, fig. 3.

$$(P—N)=0\cdot567\ P—21\cdot1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (iii)$$

P, the dew-point, is known from the afternoon wet and dry bulb observations; the value of N can, therefore, be readily calculated. The scatter of the observations about the line of best fit is smaller than in case of equation (*i*) as is also shown by the smaller magnitude of the standard error of the estimate of N from this equation *viz.*, 2·6°F.

(4) February (1915-29), (dew point — minimum) and dew point, fig. 4.

$$(P—N)=0\cdot619\ P — 29\cdot1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (iv)$$

The standard error of the estimate of N from this equation is 3·4°F, which is practically the same as for estimates from equation (ii).

The values of the constants in the above four equations may be expected to vary with the locality, the month and the time of observations; their values should, therefore, be determined for each month and for each station. These four equations contain only one independent variable; they are therefore convenient to use in practice. The graphs of the equations may be drawn once for all, from which the values of the dependent variable may be readily picked up. These equations give results nearly as accurate as the equations IX to XII containing two independent variables.

Correlation coefficients were worked out between the minimum temperature (N) of the night and each of the elements, dew point (P), dry bulb (D) and wet bulb (W) temperatures recorded at 16 hrs. (local time) in the preceding afternoon. *Multiple correlation coefficients* were also worked out between the minimum temperature (N) of the night and

(*a*) dew point (P) and dry bulb (D), and

(*b*) dry bulb (D) and wet bulb (W) temperatures

recorded in the preceding afternoon. For reasons already stated in section 2, the

coefficients were worked out separately for February and the period December-January. The values of the coefficients together with their respective standard errors are given in Table II.

TABLE II.

Correlation Coefficients between the Minimum Temperature (N) of the night and the dew-point (P), dry-bulb (D) and wet-bulb (W) temperatures of the air recorded at 16 hrs. (local time) in the preceding afternoon at Lahore.

Elements correlated	Correlation Coefficient (r)	$\pm \frac{1-r^2}{\sqrt{n}}$	Number of Observations	Remarks
	December-January (1920-29)			
1. N and P . . .	+·72	·04	144	
2. N and D	+·43	·07	,,	
3. N and W . . .	+·72	·04	,,	
4. N and W and D . .	+·73	..	,,	Multiple correlation.
5. N and P and D . .	+·73	..	,,	Do.
6. D and P	+·46	·06	,,	
7. D and W . . .	+·70	·04	,,	
	February (1915-29)			
1. N and P	+·63	·06	100	
2. N and D . . .	+·71	·05	,,	
3. N and W . . .	+·80	·03	,,	
4. N and W and D . .	+·81	..	,,	Multiple correlation.
5. N and P and D . .	+·81	..	,,	Do.
6. D and P	+·38	·09	,,	
7. D and W	+·88	02	,,	

r = Correlation coefficient, n = Number of observations.

The significance of each of the four multiple correlation coefficients was tested by analysing the variance into its two components, (*a*) that due to the

regression formula and (*b*) that due to deviations from the regression function and determining by means of the '*Z*' test [Fisher, 1925] whether the mean values of the two were significantly different. All the four coefficients were found to be significant. For example, in the case of the lowest of them in the scale of significance, it was found that the odds in favour of its significance were over 12,000 to 1.

Minimum temperature (N) of the night and the dew point (P) of the air at 16 hrs. in the preceding afternoon.

The correlation coefficient between these two elements is +·72 in December-January and +·63 in February and is significant (Table II). The regression equation between the two elements expressed in terms of the actual temperatures instead of departures is :-

(1) December-January

$$N = \cdot 427\ P + 21\cdot 5 \qquad \text{(v)}$$

(2) February

$$N = \cdot 391\ P + 28\cdot 5 \qquad \text{(vi)}$$

The standard errors of the estimates of N from (v) and (vi) are 2·6°F and 3·3°F respectively.

A relation between the dew point and the minimum temperature of the night may be expected from general physical principles. In the night a layer of air loses heat by radiation and conduction to its surroundings in consequence of which it progressively falls in temperature. When its temperature has reached the dew point, the water vapour in it may begin to condense and on account of the liberation of the latent heat of condensation, further fall in its temperature may either be arrested or at least the rate of fall of temperature may decrease. For example, on the mean of the whole period of record under examination, the minimum temperature was less than 0·1°F. higher than the dew point.

Minimum temperature (N) of the night and wet bulb temperature (W) of the air in the preceding afternoon.

The correlation coefficient between the minimum temperature of the night and wet bulb temperature of the preceding afternoon at Lahore is +·72 in December-January and +·80 in February and is highly significant (Table II). The regres-

sion equation expressed in terms of the actual temperatures under reference instead of their departures is :—

(a) December-January

$$N = \cdot 735\ W - 2\cdot 3 \qquad \text{(vii)}$$

The standard error of the estimate is 2·6°F.

(b) February

$$N = \cdot 843\ W - 3\cdot 9 \qquad \text{(viii)}$$

The standard error of the estimate is 2·5°F.

Equations vii and viii are simpler than equations xi and xii (given below) containing two independent variables, and give equally good results. The reason is that the wet bulb is far more important than the other independent variable (*i.e.* dry bulb temperature) used in equations xi and xii. In any individual case, the values of the minimum temperature may profitably be calculated from the relevant equations in each of the two pairs of equations and compared.

Multiple correlation coefficient between minimum temperature (N) of the night as dependent and dew point (P) and dry bulb temperature (D) of the air in the preceding afternoon as independent variables is +·73 in December-January and +·81 in February. The corresponding regression equations expressed in terms of the actual temperatures are :—

(a) December-January

$$N = \cdot 392\ P + \cdot 116\ D + 14\cdot 8 \qquad \text{(ix)}$$

(b) February

$$N = \cdot 260\ P + \cdot 395\ D + 4\cdot 9 \qquad \text{(x)}$$

The multiple correlation coefficient between minimum temperature (N) of the night as dependent and dry bulb (D) and wet bulb (W) temperatures of the air in the preceding afternoon as independent variables is +·73 for December-January and +·81 for February. The corresponding regression equations expressed in terms of actual temperatures are :—

(a) December-January

$$N = \cdot 837\ W - \cdot 130\ D + 0\cdot 9 \qquad \text{(xi)}$$

(b) February

$$N = \cdot 822\ W + \cdot 0150\ D - 3\cdot 8 \qquad \text{(xii)}$$

The standard error of estimate of N from each of the four equations ix to xii is about the same, namely ± 2·5°F, the probable error being ± 1·7°F. As might be expected the two pairs of equations (ix, x) and (xi, xii) give equally accurate results and the values of the minimum temperature calculated therefrom agree fairly closely with the observed values. The difference between the observed and calculated values for the two pairs of equations are given in Table III in the columns marked A and B respectively for reference.

If a difference of 4°F, (which is about 1½ times the standard error of the estimate) between the observed and calculated values be neglected, the number of

cases in which this difference was not exceeded in case of each of the equations ix to xii is given below :—

Period	Equation	Cases of difference of 4° F or less (X)	Total No. of Observations (Y)	$\frac{X}{Y}$ Per cent.
December-January (1920-29) .	ix	137	144	95
Ditto do. . .	xi	139	144	96·5
February (1915-29) . . .	x	89	100	89
Ditto . . .	xii	89	100	89
All months December-February .	ix, x	226	244	92·5
Ditto do. . .	xi, xii	228	244	93·5

The maximum value of the difference under reference is 7°F ; it occurred in February twice with equation xii and only once with equation x in one hundred observations.

It has been tacitly assumed in this discussion that there is no change in the supply of the air at the station between the time of observation and the epoch of minimum temperature. If a change occurs, *e.g.*, if the air at the time of observation is replaced either by warmer and more humid or colder and drier air, large discrepancies in the observed and calculated values of minimum temperature may be expected, since the observed values of dew point, wet bulb and dry bulb temperatures used in the equations will be no longer applicable to the air mass in which the minimum temperature of the night occurs. Such changes in the air supply in winter are mostly associated with western disturbances or depressions which generally affect the station more frequently in February than in December or January.

A. Angstrom [1920], by making approximate assumptions regarding the rate of cooling of the air at night, has deduced theoretical expressions for the minimum temperature in terms of the dew point (P), wet bulb (W), and dry bulb (D) readings in the preceding evening. His expressions are :

$$N = AP + BD + K \quad \text{. . . . .} \quad (a)$$
$$\& \; N = A'W + B'D + K' \quad \text{. . . . .} \quad (b)$$

Here A, A′, B, B′, K and K′ are constants which may vary from place to place and month to month. Equations ix and x are similar in form to expression (*a*) and equations xi and xii to (*b*). Thus the equations ix to xii developed in

this paper statistically have a physical significance. If A′ is very much larger than B′, so that the effect of the term involving B′ becomes comparatively smaller, the expression (*b*) takes the form—

$$N = A'W + K' \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (c)$$

Equations vii and viii are similar in form to (*c*). A′ is about fifty five times B′ in equation xii and about six and a half times in equation xi.

Minimum temperature and the pressure distribution.

One of the most important features of the pressure distribution over northern India in the cool season is the western disturbances or depressions which travel eastwards across northern India at the average rate of 300—400 miles per day. These disturbances are often occluded and are ill-defined on the synoptic charts. When well-marked, they generally show sharp warm and cold fronts like the depressions of the temperate latitudes. When Lahore is in the warm sector of the disturbance, the air is warm and moist. The wind is from some easterly to southerly direction and the skies are cloudy. Frost does not occur under these conditions. With the passage of the cold front, the southerly to easterly winds are replaced by westerly to northwesterly winds, much stronger, colder and drier than the normal northwesterly winds of the season. These unusually cold winds blow in the rear of the disturbance for about a couple of days when the skies are also clear. Under the combined effect of these cold winds and strong radiation from the ground at night the minimum temperature may fall down to the freezing point.

Frost may also occur during unusually long spells of dry and clear (anticyclonic) weather as a result of the cumulative effect of radiation from the ground on successive clear nights.

Conclusions.

The foregoing discussion of Lahore afternoon temperatures shows that frost occurs at the station in winter either in the cold wave in the rear of a western disturbance or during unusually long spells of clear and dry (anticyclonic) weather. Within about $\pm 2°C.$ the minimum temperature of the air on a clear night at Lahore can be forecasted from the wet bulb and dry bulb temperatures of the previous afternoon with an accuracy of over 93 per cent. The best equations to be used for the purpose are equations Nos. ix to xii. Equations vii and viii give equally good results and have the further advantage of containing only one independent variable. Equations Nos. i to iv also give satisfactory results and are quite useful as checks on the values obtained from equations vii to xii. The discrepancies observed in the remaining 6 or 7 per cent. cases are not large and are

mostly associated with the changes in the supply of the air at the station after the time of observations due to rapidly moving western disturbances. On such occasions, the afternoon temperature observations are not characteristic of the air in which the minimum temperature of the night occurs. A forecaster, provided with the facilities of the synoptic chart of the Indian forecasting area, can, in most cases, foresee and make an allowance for such occasions. On account of the importance of minimum temperature forecasts to agriculturists, the need of regular and accurate afternoon observations of temperature under standard conditions of exposure at all agricultural centres is obvious. The constants of the formulae developed in this paper should be determined for each locality. If this is done, losses through damaging frosts and harmfully low temperatures could be reduced enormously by adopting protective measures in time.

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TABLE III.

Values of minimum temperature (N) *and of the dew-point* (P), *wet bulb* (W) *and dry bulb* (D) *temperatures of the air at 16 hrs. (local time) in the preceding afternoon at Lahore in December (1920-29), January (1920-29) and February (1915-29).*

Date	Temperature in °F				Minimum temperature calculated minus observed (°F)	
	Dew-point (P)	Dry-bulb (D)	Wet-bulb (W)	Minimum (N)	A from equations IX & X	B from equations X & XII
1	2	3	4	5	6	7
4th January 1925 . .	46	68	57	41	0	−1
6th „ „ . .	34	62	50	36	−1	−1
9th „ „ . .	41	65	54	39	−1	−2
10th „ „ .	44	67	55	40	0	−2
11th „ „ . .	43	67	55	41	−2	−3

TABLE III—*contd.*

Date	Temperature in °F				Minimum temperature calculated minus observed (°F)	
	Dew-point (P)	Dry-bulb (D)	Wet-bulb (W)	Minimum (N)	A from equations IX & X	B from equations XI & XII
1	2	3	4	5	6	7
12th January 1925 . .	39	67	54	36	2	1
13th ,, ,,	34	66	52	35	1	1
14th ,, ,, . .	28	65	50	35	—2	—1
15th ,, ,, . .	34	67	52	37	—1	—1
22nd ,, ,, . .	35	58	48	35	0	—2
23rd ,, ,, . .	30	61	48	37	—3	—4
28th ,, ,, . .	36	59	49	37	—1	—3
29th ,, ,, . .	29	63	49	36	—3	—2
30th ,, ,, . .	33	65	51	36	—1	—1
8th ,, 1926 . .	49	64	56	42	—1	—3
9th ,, ,, . .	48	65	56	42	—1	—3
17th ,, ,, . .	47	67	57	41	0	—1
18th ,, ,, . .	35	67	53	37	—1	—1
20th ,, ,, . .	36	69	54	36	1	1
21st ,, ,, . .	40	70	56	40	—1	—1
24th ,, ,, . .	46	71	58	41	0	—1
25th ,, ,, . .	44	72	58	42	—2	—2
14th ,, 1927 . .	39	64	53	35	2	2
15th ,, ,, . .	38	66	53	35	2	1
16th ,, ,, . .	37	67	53	36	1	0
17th ,, ,, . .	37	69	54	35	2	2
19th ,, ,, . .	38	68	54	41	—3	—4
20th ,, ,, . .	40	71	56	38	1	0
21st ,, ,, . .	40	70	55	40	0	—2

TABLE III—*contd.*

Date	Temperature in °F				Minimum temperature calculated minus observed (°F)	
	Dew-point (P)	Dry-bulb (D)	Web-bulb (W)	Minimum (N)	A from equations IX & X	B from equations XI & XII
1	2	3	4	5	6	7
22nd January 1927 . .	41	70	56	41	—2	—2
25th „ „ . .	39	68	54	36	2	1
9th „ 1928 . .	50	70	59	44	—2	—3
10th „ „ . .	47	69	58	40	1	0
21st „ „ . .	41	64	53	40	—2	—3
4th „ 1929 . .	42	67	55	41	—2	—3
5th „ „ . .	45	69	57	38	2	1
6th „ „ . .	44	69	56	38	2	1
10th „ „ . .	43	70	57	40	0	—1
18th „ „ . .	44	70	57	40	0	—1
19th „ „ . .	37	69	54	37	0	0
20th „ „ . .	43	69	56	37	3	2
21st „ „ . .	35	69	54	41	—5	—4
30th „ „ . .	18	50	39	29	—1	—2
31st „ „ . .	23	53	42	32	—2	—3
6th „ 1927 . .	39	67	54	39	—1	—2
7th „ „ . .	42	65	54	37	2	0
8th „ „ . .	38	63	51	34	3	1
9th „ „ . .	39	66	53	33	4	3
10th „ „ . .	33	67	52	32	3	3
11th „ „ . .	36	65	52	33	3	3
1st December 1925 . .	48	75	61	40	2	2
2nd „ „ . .	47	76	61	41	1	1
3rd „ „ . .	46	76	60	41	1	0

TABLE III—*contd.*

Date	Temperature in °F				Minimum temperature calculated minus observed (°F)	
	Dew-point (P)	Dry-bulb (D)	Wet-bulb (W)	Minimum (N)	A from equations IX & X	B from equations XI & XII
1	2	3	S	5	6	7
4th December 1925 . .	48	76	61	41	1	1
5th „ „ . .	53	74	62	43	1	0
6th „ „ . .	53	74	62	42	2	1
9th „ „ . .	48	72	59	41	1	0
10th „ „ . .	48	72	59	39	3	2
11th „ „ . .	48	71	59	39	3	2
12th „ „ . .	49	72	59	40	2	1
14th „ „ . .	49	70	59	41	1	0
15th „ „ . .	48	69	58	40	2	0
16th „ „ . .	50	69	59	39	3	2
17th „ „ . .	47	70	58	38	3	2
18th „ „ . .	42	72	57	36	3	3
19th „ „ . .	44	72	58	35	5	4
20th „ „ . .	43	68	56	35	4	4
26th „ „ . .	44	68	56	37	3	2
27th „ „ . .	43	68	56	36	3	3
28th „ „ . .	42	71	56	35	4	3
29th „ „ . .	43	71	57	36	4	3
30th „ „ . .	44	70	57	37	3	2
9th „ 1926 . .	54	71	62	45	—1	—2
15th „ „ . .	47	66	56	43	—2	—4
16th „ „ . .	46	67	57	40	1	0
19th „ „ . .	39	69	55	38	0	0
20th „ „ . .	41	68	55	37	2	1

TABLE III—*contd.*

Date	Temperature in °F				Minimum temperature calculated minus observed (°F)	
	Dew-point (P)	Dry-bulb (D)	Wet-bulb (W)	Minimum (N)	A from equations IX & X	B from equations XI & XII
1	2	3	4	5	6	7
21st December 1926 . .	43	68	55	37	2	1
22nd „ „ . .	36	69	54	34	3	3
24th „ „ . .	34	68	53	35	1	1
27th „ „ . .	37	71	55	34	3	4
28th „ „ . .	39	69	55	36	2	2
29th „ „ . .	40	71	56	35	4	3
30th „ „ . .	41	73	57	36	3	3
31st „ „ . .	37	74	56	36	2	2
16th „ 1927 . .	43	71	57	38	2	1
22nd „ „ . .	53	69	60	45	—2	—3
4th „ 1928 . .	47	63	55	43	—2	—4
5th „ „ . .	44	63	54	40	—1	—2
8th „ „ . .	50	67	58	44	—2	—4
17th „ „ . .	47	68	57	41	0	—1
18th „ „ . .	39	70	55	39	—1	—1
19th „ „ . .	43	70	57	39	1	0
20th „ „ . .	50	71	60	41	2	1
21st „ „ . .	49	68	58	40	2	0
23rd „ „ . .	48	72	59	41	1	0
31st „ „ . .	45	61	53	39	0	—2
1st „ 1929 . .	45	75	60	43	—2	—2
28th „ „ . .	35	61	50	35	0	0
15th „ 1927 . .	55	68	61	49	—5	—6
1st „ 1920 . .	38	78	58	45	—6	—6

TABLE III—*contd.*

Date	Temperature in °F				Minimum temperature calculated minus observed (°F)	
	Dew-point (P)	Dry-bulb (D)	Wet-bulb (W)	Minimum (N)	A from equations IX & X	B from equations X & XII
1	2	3	4	5	6	7
2nd December 1920 . .	48	77	62	44	—1	—1
3rd „ „ . .	45	77	60	45	—4	—4
4th „ „ . .	39	74	57	42	—3	—3
5th „ „ . .	35	71	54	40	—3	—3
9th „ „ . .	40	75	57	38	1	1
10th „ „ . .	38	73	56	36	2	2
11th „ „ . .	39	72	56	37	1	1
12th „ „ . .	40	73	57	37	2	2
13th „ „ . .	42	76	59	38	3	2
14th „ „ . .	40	75	58	40	—1	—1
31st „ „ . .	35	70	54	36	1	1
6th „ 1921 . .	57	73	61	49	—3	—4
7th „ „ . .	53	70	61	47	—3	—4
8th „ „ . .	51	70	60	44	—1	—2
5th „ 1922 . .	50	76	62	48	—5	—5
8th „ „ . .	53	74	62	47	—3	—4
25th „ „ . .	44	63	53	38	1	—1
31st „ „ . .	35	64	51	37	—1	—2
12th „ 1923 . .	33	67	52	37	—2	—1
20th „ „ . .	45	71	58	41	0	—1
21st „ „ . .	41	71	56	41	—2	—3
24th „ „ . .	48	71	59	45	—3	—4
25th „ „ . .	47	72	59	43	—1	—2
26th „ „ . .	44	71	57	41	—1	—2

TABLE III—*contd.*

Date	Temperature in °F				Minimum temperature calculated minus observed (°F)	
	Dew-point (P)	Dry-bulb (D)	Wet-bulb (W)	Minimum (N)	A from equations IX & X	B from equations XI & XII
1	2	3	4	5	6	7
27th December 1923 . .	38	69	55	39	—1	—1
28th „ „ . .	31	68	52	38	—3	—3
29th „ „ . .	35	70	54	37	0	0
31st „ „ . .	34	70	54	38	—2	—1
18th „ 1924 . .	49	70	59	44	—2	—3
19th „ „ . .	47	67	57	45	—4	—5
2nd January 1920 . .	46	68	57	39	2	0
6th „ „ . .	49	68	58	41	1	—1
7th „ „ . .	47	71	58	38	3	2
17th „ „ . .	51	68	59	42	1	—1
18th „ „ . .	47	69	58	41	0	—1
25th „ „ . .	46	64	55	42	—2	—3
8th „ 1921 . .	37	73	56	40	—2	—2
16th „ „ . .	44	69	57	44	—4	—4
17th „ „ . .	40	66	54	37	1	0
23rd „ „ . .	43	69	56	44	—4	—5
27th „ „ . .	46	71	58	41	0	—1
30th „ „ . .	36	73	55	40	—3	—3
29th „ 1923 . .	51	70	60	46	—3	—4
			February			
3rd February 1923 . .	42	71	57	39	5	5
5th „ „ . .	25	67	50	42	—4	—4
6th „ „ . .	28	70	52	39	1	1
11th „ „ . .	33	61	49	38	0	0

TABLE III—*contd.*

Date	Temperature in °F				Minimum temperature calculated minus observed (°F)	
	Dew-point (P)	Dry-bulb (D)	Wet-bulb (W)	Minimum (N)	A from equations IX & X	B from equations XI & XII
1	2	3	4	5	6	7
12th February 1925 . .	31	60	48	39	—2	—2
13th „ „ . .	27	66	50	37	1	1
14th „ „ . .	33	71	54	46	—4	—4
16th „ „ . .	45	68	56	48	—4	—5
17th „ „ . .	33	63	50	44	—6	—6
23rd „ „ . .	28	72	53	37	4	4
3rd „ 1926 . .	55	71	62	48	—1	0
4th „ „ . .	43	71	57	45	—1	—1
7th „ „ . .	43	69	56	42	1	1
16th „ „ . .	44	74	59	42	4	4
17th „ „ . .	33	72	54	41	1	1
20th „ „ . .	43	75	59	45	1	1
23rd „ „ . .	47	81	63	49	0	0
25th „ 1927 . .	33	67	53	39	1	2
16th „ 1928 . .	49	73	60	47	—1	0
17th „ „ . .	43	75	59	45	1	1
20th „ „ . .	48	79	62	50	—1	—2
21st „ „ . .	46	81	62	51	—2	—3
22nd „ „ . .	45	82	62	48	1	0
23rd „ „ . .	42	80	61	48	0	—1
4th „ 1929 . .	35	64	51	36	3	3
16th „ „ . .	40	71	56	43	0	0
17th „ „ . .	43	72	57	42	3	2
19th „ „ . .	43	75	59	46	0	0

TABLE III—*contd.*

Date	Temperature in °F				Minimum temperature calculated minus observed (°F)	
	Dew-point (P)	Dry-bulb (D)	Wet-bulb (W)	Minimum (N)	A from equations IX & X	B from equations XI & XII
1	2	3	4	5	6	7
26th February 1927 . .	32	70	53	41	0	0
27th " " . .	28	73	53	46	—5	—5
10th " 1920 . .	39	59	50	38	0	0
11th " " . .	36	63	51	39	0	0
14th " " . .	47	69	58	41	3	4
15th " " . .	43	74	58	44	1	1
5th " 1921 . .	39	65	53	39	2	2
6th " " . .	38	67	54	39	2	3
8th " " . .	37	71	55	42	1	1
9th " " . .	24	68	50	37	1	1
14th " " . .	32	73	55	45	—3	—2
15th " " . .	30	76	56	45	—2	—2
16th " " . .	33	79	58	45	0	0
17th " " . .	36	81	59	45	1	1
18th " " . .	35	83	60	48	—1	—1
19th " " . .	40	85	62	48	1	0
20th " " . .	42	86	63	48	2	1
6th " 1922 . .	46	70	58	43	2	2
7th " " . .	44	72	58	43	2	2
8th " " . .	48	73	60	49	—3	—2
9th " " . .	45	77	61	50	—3	—3
16th " " . .	51	79	63	49	0	0
25th " " . .	46	78	61	53	—5	—5
26th " " . .	42	78	60	47	0	0

TABLE III—*contd.*

Date	Temperature in °F				Minimum temperature calculated minus observed (°F)	
	Dew-point (P)	Dry-bulb (D)	Wet-bulb (W)	Minimum (N)	A from equations IX & X	B from equations XI & XII
1	2	3	4	5	6	7
26th February 1923 . .	45	70	57	47	—3	—3
10th „ 1924 . .	45	63	54	41	0	1
11th „ „ . .	42	65	54	43	—2	—1
15th „ „ . .	41	68	55	42	0	1
16th „ „ . .	37	71	55	43	0	0
17th „ „ . .	42	71	56	50	—6	—7
18th „ „ . .	39	74	57	44	0	0
19th „ „ . .	39	76	58	45	0	0
20th „ „ . .	44	79	61	47	1	0
21st „ „ . .	45	78	61	49	—2	—2
1st „ 1919 . .	48	62	55	43	—1	—1
5th „ „ . .	48	67	57	43	1	1
6th „ „ . .	40	69	55	41	2	2
13th „ „ . .	41	76	59	45	0	1
21st „ „ . .	48	75	61	46	1	1
2nd „ 1918 . .	36	72	55	38	5	4
3rd „ „ . .	34	71	54	36	6	6
4th „ „ . .	32	69	53	37	4	4
7th „ „ . .	36	73	56	38	5	5
8th „ „ . .	33	73	55	45	—3	—2
14th „ „ . .	46	75	60	46	1	1
15th „ „ . .	45	76	60	44	3	3
16th „ „ . .	38	77	58	44	1	1
17th „ „ . .	41	78	59	45	1	1

TABLE III—*concld.*

Date	Temperature in °F				Minimum temperature calculated minus observed (°F)	
	Dew-point (P)	Dry-bulb (D)	Web-bulb (W)	Minimum (N)	A from equations IX & X	B from equations XI & XII
1	2	3	4	5	6	7
1st February 1917 . .	37	73	56	38	5	5
5th ,, ,, . .	42	72	57	41	3	3
10th ,, ,, . .	38	74	57	42	2	2
11th ,, ,, . .	39	76	58	44	1	1
16th ,, ,, . .	52	81	65	52	—1	—1
17th ,, ,, . .	54	85	67	53	0	—1
18th ,, ,, . .	50	83	65	53	—2	—2
22nd ,, ,, .	41	77	59	47	—1	—1
23rd ,, ,, . .	32	74	55	39	4	4
24th ,, ,, . .	38	77	58	43	2	2
25th ,, ,, . .	33	78	57	44	0	0
26th ,, ,, . .	34	79	58	48	—3	—3
2nd ,, 1916 . .	44	74	59	47	—1	—1
3rd ,, ,, . .	37	74	56	44	0	—1
4th ,, ,, . .	41	70	56	50	—7	—7
5th ,, ,, . .	20	65	47	41	—5	—5
6th ,, ,, . .	30	57	46	36	—1	—1
7th ,, ,, . .	27	60	47	34	2	2
21st ,, ,, . .	42	76	59	46	0	0
26th ,, ,, . .	49	76	61	49	—1	—2
27th ,, ,, . .	40	76	58	49	—4	—4
28th ,, ,, . .	32	78	57	44	0	0
23rd ,, 1915 . .	44	75	59	46	0	0
24th ,, ,, . .	40	75	58	47	—2	—2

SOME STUDIES IN RESPIRATION AND OTHER METABOLIC ACTIVITIES IN BERRIES OF THE GRAPE VINE (*VITIS VINIFERA*, LINN).

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INTRODUCTION.

The investigation reported in the paper relates to the study of respiration and other metabolic activites in grape berries from the time of bearing to maturity. The work was carried out in 1929 in the Botanical laboratory, Punjab Agricultural College, Lyallpur. So far as the authors have been able to trace by the study of literature on the subject, it appears that the following brief references point to the work done on metabolic processes in plants including fruits.

Ludwig Jost [1907] holds that protoplasm is the seat of respiration and mentions that even the same organ of an individual plant in different stages of development exhibits the widest possible variation as far as the respiratory activity is concerned. " Flowers, embryonic organs, germinating seeds, buds, etc., appear to respire more vigorously than full grown roots, stems or leaves." Palladin [1921] says " On the amount of protoplasm present in a tissue depends the amount of enzymes and the latter determine the rate of respiration as long as the supply of carbohydrates is adequate. Kidd, West and Briggs [1921] have witnessed a fall in the respiratory index of *Helianthus annus* and of its various parts with the increase in age.

Blackman and Parija [1928] state, " Any change that takes place in the metabolic activity of the cell must run in close parallel with the corresponding change in the respiration of that cell ". Richards [1896] observed an increase in the respiratory activity after injury to plant tissue. He ascribes this increased respiration to an effort on the part of the plant to recover from the injury. Luthra [1924] while studying the effects of dry and moist air on the rate of respiration and break-

down of ripe pears found that dry air hastened the rate of break-down as compared with moist air. The rate of respiration showed a marked decline with the lapse of time. Archbold [1925] holds that a high nitrogen content in general is accompanied by a high respiration rate and during storage other factors besides nitrogen content come into play which diminish the respiration rate. Gore [1911] says "The rate of respiration is not a direct function of content of sugars or of acids and does not depend on size, as Japanese Persimons are richer in sugars than strawberries, yet are less active; oranges and lemons, which differ greatly in acid contents, have about the same respiratory activity. Red currants differ greatly in respiratory activity from black currants although they are nearly the same in size." Spoehr and Megee [1923] hold that "A carbohydrate content alone cannot be taken as an index of the rate of respiration". According to them presence of amino acids in a tissue determines its respiratory activities. Appleman [1916] found an invariable parallelism between the respiratory intensity of sweet corn and the Catalase activities in the expressed juice.

Scheme of the investigation.

The subject has been studied in the following respects :-

A. Determination of the rate of respiration of grape berries of different ages.

These estimations were made in the laboratory (1) on bunches removed from the plant and (2) *in situ i.e.,* while the bunches were on the plant. Experiments on grape bunches *in situ* were carried on during the day from 6 A.M. to 12 noon and at night from 9 P.M. to 3 A.M.

B. A biochemical study of metabolic changes throughout the life-cycle from the time of bearing to maturity. The following determinations were made at intervals.

1. Total solids.
2. Total reducing sugars.
3. Total titrable acids.
4. Nitrogen contents.
5. Water-insoluble residue.
6. Specific gravity of the juice.
7. Cellulose.

C. Study of correlation between the rate of respiration and sugars. Determination of co-efficient of correlation between sugars and acids.

(A) Studies on Respiration.

The work was undertaken to discover if there was any correlation between the intensity of respiration and the biochemical changes that occur in grape berries dur-

ing the process of maturation. The nature of the problem necessitated a study of the activity of respiration and chemical changes in developing grape berries. For this purpose two Indian varieties of grape vines named *jaishi* and *tur*, growing in the vineyard of the Botanical Section, Punjab Agricultural College, Lyallpur, were selected. These varieties were introduced from Peshawar in 1910. Berries of *jaishi* are white and oblong and those of *tur* are black and round. Flowers appeared about the 20th of March and bunches were labelled as soon as the berries had set. Exact age of the bunches was known when they were subjectsd to physiological studies.

Apparatus employed.—The method employed for determining the rate of respiration was one of gaseous exchange. A constant current of air free of carbon dioxide was maintained through a respiration chamber by means of a suction pump connected with a water tap and controlled by a mercury pressure regulator. The current of air entering the respiration chamber was cleared of carbon dioxide by passing through a soda lime tower and a series of bottles containing 20 per cent. sodium hydroxide solution. Before entering the respiration chamber, the air was let through a small bottle containing barium hydroxide. The absence of any precipitate ensured that the air was completely freed of CO_2. Carbon dioxide evolved by the berries was absorbed in a known quantity of standardized $\frac{N}{10}$ NaOH solution filled in Reiset towers. Air escaping from the Reiset tubes was again tested for the complete absorption of CO_2 by barium hydroxide.

Experimental procedure.—In order to map out variations in the respiratory activity of grape berries as influenced by metabolic changes, entire bunches of known age were removed from time to time and taken to the laboratory for the determination of the rate of respiration. Bunches were taken for the estimation of respiration because it was feared that removal of berries alone would make them more liable to a fungus attack and wounding was likely to augment the CO_2 output. The bunch was weighed before and after the experiment and loss in weight was recorded each time. It was then quickly transferred to the respiration chamber, which had been previously exhausted of CO_2 by running the apparatus empty for 8 hours. After putting in the bunch, the apparatus was again run for half an hour. Reiset tubes were then connected with the respiration chamber. For each determination, the experiment was run for not less than 22 hours.

During the course of these estimations, care was taken to keep the apparatus air-tight. Respiration chamber was always kept covered by a piece of black cloth to stop carbon assimilation. The bottles containing 20 per cent. NaOH solution used for rendering the air free of carbon dioxide before it entered the chamber, were changed from time to time.

The determinations were made at the room temperature, which varied as the season advanced (Table III-A); care being, however, taken to keep the temperature as uniform as possible during the course of each determination by immersing the respiration chamber in a water bath. The temperature, in this manner, was kept constant to within two degrees, during the experiment.

At the close of the experiment, Reiset tubes were thoroughly washed with boiled distilled water. The CO_2 given out was quantitatively estimated by titrating the solution against N H_2SO_4 using phenolphthalein and methyl orange as indicators. The amount of NaOH used up in the reaction was ascertained and from this total CO_2 evolved during the duration of the experiment was worked out.

To eliminate any possible error due to washing of the absorption tubes and traces of CO_2 finding their way from the air, the apparatus was run for 24 hours periodically as a control. The NaOH in the absorption tubes was titrated and the amount of alkali used up in this way was subtracted from that taken up by the CO_2 evolved by the berries. The results were expressed on initial weight of the berries as c. c. of CO_2 evolved per 100 grms. of berries per hour.

Results.

Determinations of respiratory activity were begun, when berries were two days old in the case of *jaishi* and about five days old in the case of *tur*. At these stages berries had attained an appreciable size fit for handling. Experiments were carried on till berries had completely matured. The results are given in Table I and the range of variation is illustrated in graph Fig. 1.

It appears from the data that respiration was very active, when berries were young, but the rate gradually slowed down and became fairly constant later, as berries advanced in age. The rate of respiration declined very rapidly during the first thirty days after setting; after which period the decline was not so well pronounced. On the 35th and 52nd day a slight rise is noticeable. This was due to the fact that some of the berries, during the course of the experiment, were attacked by a mould and caused fermentation. The bunches were taken out, respiration chamber was sterilized and experiments were started again. After that, no such fluctuations occurred and the curve shows a steady fall till the respiratory activity reaches a minimum. The minima in the curve correspond to complete maturity of the berries.

Reference to experimental evidence illustrates that the rate of respiration fell from 30·49 c. c. of CO_2 per hundred grms. per hour, when berries were young to 4·79 c. c. of CO_2 when berries had fully matured.

A similar fall in respiration rate was discovered in the case of the *tur* variety. Analytical data obtained in this case strictly corroborate that obtained in *jaishi*. The results are given in Table II and graphed in Fig. 1.

In 1930 the experiments were repeated and four determinations were made with three bunches of the same age in each lot. The results showed slight variations due to the difference of temperature, but on the whole corroborated the data of 1929.

TABLE I.

Showing the rate of respiration in the Jaishi *Vine throughout the life cycle of the berries.*

Date of commencement of the experiment	Age of berries in days	Duration of the experiment	Output of CO_2 in ccs. per 100 grms. of berries per hour
15th April 1929	2	22 hours	30·49
20th April 1929	5	24 ,,	20·27
24th April 1929	8	22 ,,	15·88
27th April 1929	10	24 ,,	11·86
6th May 1929	15	25 ,,	10·81
14th May 1929	20	24 ,,	7·47
18th May 1929	25	26 ,,	7·56
24th May 1929	30	24 ,,	7·26
26th May 1929	35	27 ,,	8·40
29th May 1929	40	28 ,,	6 99
30th May 1929	47	28 ,,	6·86
4th June 1929	52	26 ,,	7·57
7th June 1929	56	26 ,,	6·03
12th June 1929	60	27 ,,	5·97
16th June 1929	65	26 ,,	5·87
20th June 1929	70	23 ,,	4·85
25th June 1929	75	24 ,,	4·79

TABLE II.

Showing the rate of respiration of grape berries in the tur *Vine.*

Date of commencement of the experiment	Age of berries in days	Duration of the experiment	Output of CO_2 in ccs. per 100 grms. of berries per hour
25th April 1929	3	23 hours	25·69
30th April 1929	5	22 "	15·46
8th May 1929	15	25 "	13·61
20th May 1929	29	28 "	7·69
27th May 1929	36	24 "	9·27
1st June 1929	40	22 "	7·67
10th June 1929	50	26 "	7·37
14th June 1929	55	26 "	4·67

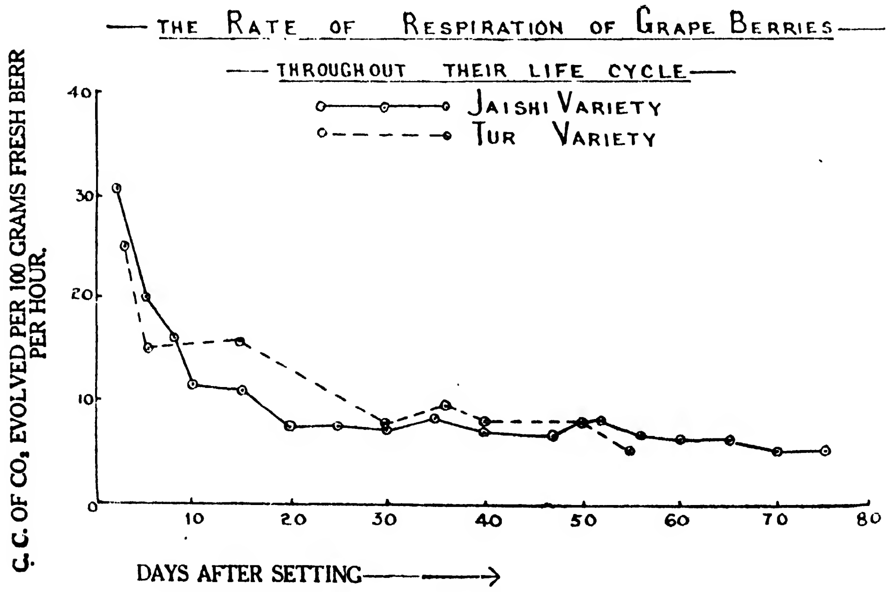

Fig. 1.

RESPIRATION OF GRAPE BERRIES *IN SITU* DURING DAY TIME.

Kidd, West and Briggs [1921] while studying respiratory index of detached parts of *Helianthus annus* determined respiration of an entire plant *in situ* in the field. They noticed a strict parallelism between the values obtained from cut and entire plant *in situ* to the extent that there was a continuous falling off in the respiration rate with age in both cases.

With a view to find out if such a bulky material as grape berries would yield similar results, the experiment referred to was conducted.

Apparatus used.—In the absence of a water tap in the field, an aspirator was employed in place of the suction pump, etc. Experience showed that the aspirator did not exert a sufficient force to draw in air through Reiset towers. Three bubblers with spiral tubes were therefore employed and each contained 100 c.c. of $\frac{N}{20}$ NaOH solution for the absorption of CO_2. The apparatus used for the removal of CO_2 from air entering the respiration chamber and the procedure adopted were the same as already described.

Experimental procedure.—Only one plant of *jaishi* variety was selected for this purpose. Bunches, which could be conveniently handled, were selected. The respiration rate was estimated once a week and was continued till the bunch was 68 days old. At this stage the experiment was stopped, because misleading values were obtained due to the appearance of a fungus on the berries. The bunch under investigation was carefully introduced into a wide mouthed glass bottle. A slit was kept in the cork through which peduncle of the bunch could pass. All joints were made air tight by wax. The plant chamber was then placed in a water bath and was kept covered by a piece of black cloth in order to keep out light. The apparatus was run empty for half an hour to expel CO_2 from the respiration chamber before CO_2 absorption bubblers were connected with the respiration chamber. After half an hour bubblers were attached to the plant chamber and the experiment was allowed to continue for six hours each time. Temperature of the plant chamber was taken occasionally by a thermometer inserted in the chamber (Table III). Reference to Table III shows that the average temparature varied only from 2 to 3 degrees during the course of determinations except on 20th April 1929 when it was 84 degrees F due to clouds but it shows a rapid rise from 6-7 A.M. to 12 Noon-1 P.M. in almost all the experiments.

At the close of experiment, the bunch was taken out and its volume was measured by water displacement method, because weighing was impracticable. The bubblers were taken to the laboratory, washed with boiled distilled water and CO_2 was quantitatively estimated by the method already described. The results were expressed as c.c. of CO_2 evolved per 100 c.c. of the bunch per hour.

Results.---The results obtained with detached bunches in the laboratory were also expressed on volume basis in order to make them strictly comparable with those got *in situ*. From the data compiled in Tables III and III-A and graphed in Fig.2, a close agreement between the values obtained in the field and laboratory is noticeable to the extent that respiratory activity shows a gradual decline as the berries mature. Values obtained in the laboratory and the field when the berries were 2 days old are identical and this is due to the average temperature in both the cases being nearly the same. In the field higher values are obtained for the determinations made on berries 8, 12, 19 and 26 days old than the corresponding figures got in the laboratory. Higher temperature in the field in those days seems to be responsibile for the increased respiratory activity there, since later on, when average temperature of the laboratory exceeded the average temperature in the field, as summer advanced, the results tended to be slightly higher in the case of laboratory. For practical purposes, however, the results are similar in both the cases and they are confirmed by the results of Kidd, West and Briggs.

Indirectly the results also confirm the view that there is greater respiratory activity with the rise of temperature.

TABLE III.

Showing the rate of respiration of grape berries in situ.

Date of commencement of the experiment	Age of berries in days	Average temperature of the chamber for the day Degrees F	Output of CO_2 in ccs. per 100 c.c. of berries per hour	Duration of the experiment in hours
20th April 1929 . . .	2	84	32·48	6
24th „ „	8	92·7	23·34	6
29th „ „	12	95·9	23·58	6
6th May „	19	91·2	18·98	5
14th „ „	26	94·0	12·48	6
21st „ „	33	90·6	8·54	6
28th „ „	40	89·5	5·83	6
4th June „	47	95·2	6·94	6
11th „ „	54	93·7	6·65	6
18th „ „	61	92	6·21	6
25th „ „	68	93·5	5·96	6

TABLE III-A.

Showing the rate of respiration of grape berries in the laboratory.

Date of commencement of the experiment	Age of berries in days	Average temperature of the chamber for the day Degrees F	Output of CO_2 C. C's per 100 cc of berries per hour	Duration of the experiment in hours
15th April 1929 . .	2	84·2	34·01	22
22nd April 1929 . .	5	85	24·0	24
24th April 1929 . .	8	84·2	16·45	22
27th April 1929 . .	10	86·2	11·97	24
6th May 1929 . .	15	89·1	10·94	25
14th May 1929 . .	20	90·6	7·01	24
18th May 1929 . .	25	91·8	7·55	26
24th May 1929 . .	30	93·8	7·53	24
26th May 1929 . .	35	93·9	8·65	27
29th May 1929 . .	40	96·2	7·13	28
30th May 1929 . .	47	97·3	6·91	28
4th June 1929 . .	52	99·6	7·96	26
7th June 1929 . .	56	96·2	7·02	26
12th June 1929 . .	60	100·1	6·11	27
16th June 1929 . .	65	94·2	6·03	26

RESPIRATION *IN SITU* DURING NIGHT.

These studies were further carried out to ascertain the behaviour of berries with regard to respiratory activity at night. Ten observations were made from time to time from 9 P.M. to 3 A.M.

Apparatus and experimental procedure.—The apparatus used and the method followed were exactly the same as already described except this that the experiment was conducted at night.

Results.—Data obtained are represented in Table IV and Fig. 2 Page 704. Examination of the values obtained during day and night reveals that under the conditions of the experiment there is no difference between the respiration rates in the two cases. The general form of the curves in both agrees with one another, but slightly low figures are obtained at night and this difference is evidently due to

lower temperature. In no case the average temperature exceeded 89° F but during the day time it was as high as 95°F.

TABLE IV.

Showing the rate of respiration in situ *at night.*

Date of commencement of the experiment	Age of berries in days	Average temperature in degrees from 9 P.M. to 3 A.M. Degrees F	Output of Co_2 per 100 cc of berries per hour	Duration of the experiment in hours
10th May 1929 . .	2	79·6	29·76	6
14th „ „ . .	6	79·5	22·36	6
21st „ „ . .	13	84·7	19·14	6
28th „ „ . .	20	74·2 showers of rain.	6·47	6
4th June 1929 . .	27	89·5 stormy.	7·90	6
11th „ „ . .	34	85·2	6·13	6
18th „ „ . .	41	84·2	5·65	6
25th „ „ . .	48	83·5	5·32	6
2nd July 1929 . .	56	84·7	4·47	6
9th „ „ . .	63	85·2	3·71	6

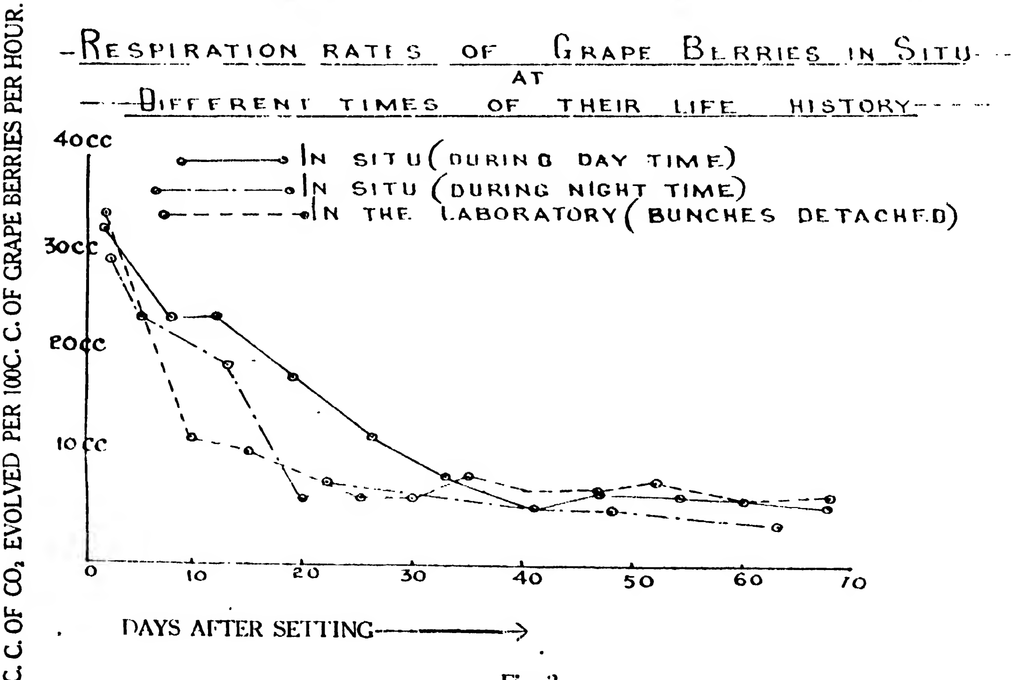

Fig. 2.

(B) Metabolic Changes.

Chemical changes accompanying the metabolic activities of grape berries during their life history were studied with reference to the following constituents.

1. Total solids.
2. Reducing sugars.
3. Total titrable acids.
4. Nitrogen.
5. Water-insoluble residue.
6. Specific gravity of the juice.
7. Cellulose.

Methods employed for the estimation of the above constituents and the results obtained were as follows :—

1. *Total solids.*—The amount of dry matter present in the berries at different times during their growth was estimated every week. A known weight of berries was placed in an oven, at a temperature of 90°C. Of course it is not possible to completely dry the sample at this temperature but heating beyond 90°C is likely to lead to the decomposition of sugars, so this temperature was never exceeded. The best method for estimating the amount of dry matter in the berries would have surely been that of drying them in a vacuum oven but arrangements could not be made for it.

Results.—Table V below gives the variation in the dry matter for both *jaishi* and *tur* varieties. Looking at the figure for *jaishi* it will be seen that the percentage of dry matter on the 3rd day after setting is rather high, then it goes on decreasing till about the 3rd week, when it continues to rise gradually up to the end of the ripening period. It is rather difficult to explain the excess of dry matter during the first week of setting, since as it will be noticed later on, the amount of cellulose material is almost constant throughout the life cycle of the fruit. This probably means that the percentage amount of proteins and sugars and other non-cellular material is much less in the beginning.

The excess of dry matter in the initial stage is also noticeable in the case of the *tur* variety. From about the second week onward the total solids, however, show a steady increase uptil the end. The results are represented in fig. 3.

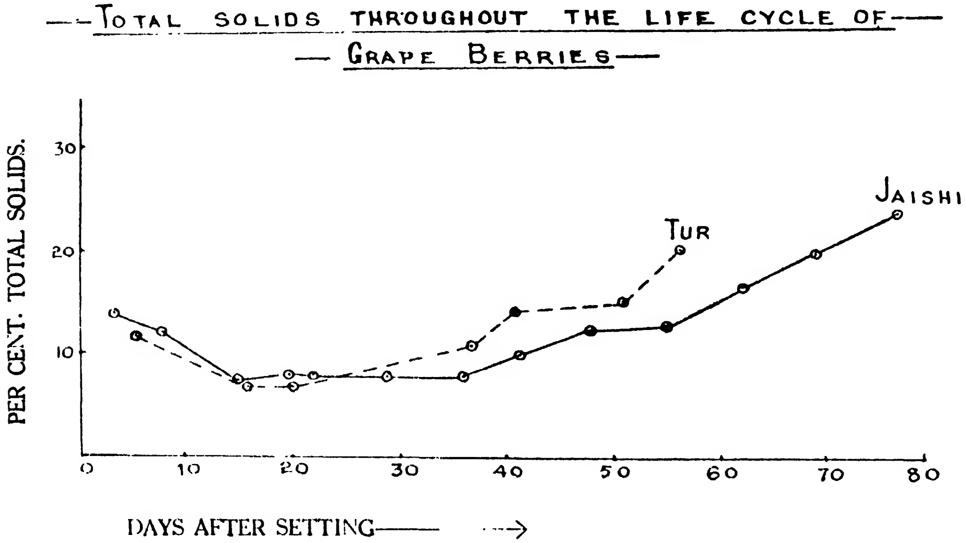

Fig. 3.

TABLE V.

Showing percentage of total solids in grape berries of both the varieties at different ages.

Jaishi			*Tur*		
Date of estimation	Age of berries in days	Percentage of total solids	Date of estimation	Age of berries in days	Percentage of total solids
15th April 1929 .	3	13·75	28th April 1929 .	5	11·17
19th April 1929 .	7	11·73	3rd May 1929 .	15	6·71
26th April 1929 .	14	7·48	10th May 1929 .	19	7·29
30th April 1929 .	19	7·83	20th May 1929 .	29	9·41
3rd May 1929 .	21	8·0	27th May 1929 .	36	11·30
10th May 1929 .	28	8·4	3rd June 1929 .	40	13·73
17th May 1929 .	35	8·45	10th June 1929 .	50	15·25
23rd May 1929 .	40	9·97	17th June 1929 .	55	20·31
30th May 1929 .	47	12·62			
6th June 1929 .	54	13·30			
13th June 1929 .	61	16·65			
20th June 1929 .	68	20·25			
27th June 1929 .	75	23·75			

2. *Reducing sugars.*—In the early stages, berries of both the *jaishi* and *tur* grape vines are green in colour and it was expected that prior to formation of sugars there would be starch produced. But microscopic examination and chemical tests failed to reveal the presence of starch grains. It appears that sugars are the direct product of carbon assimilation.

Before reducing sugars can be estimated, it is necessary to obtain the juice in a suitable form. For this purpose the method recommended by Haynes [1925] was used. A known amount of berries was rammed down into silver-plated metal cylinders and left over night in freezing mixture. Next morning the berries along with the juice that had come out during the night, were crushed in a pestle-mortar and the entire mass ground to a fine pulp and transferred to a 250 c. c. flask with the help of distilled water. The juice was clarified by the addition of basic lead acetate and stirred. The flask after being shaken thoroughly was allowed to stand for 10 to 15 minutes, so that proteins and other allied bodies may settle down. In order to remove the excess of lead, powdered sodium carbonate was added till the solution was just alkaline. The solution was now made up to the mark, well shaken and filtered. The first portions of the filtrate were again transferred to the filter paper, till a clear solution was obtained. This juice was used for the estimation of reducing sugars, which was done as follows.

20 c.c. of the Fehling's solution were prepared according to the method of (Ling and Jones) and were titrated against the juice obtained from the berries as described above and diluted to a suitable strength. Ferrous ammonium sulphate and ferrous thiocyanate were used as external indicator. The end point was detected by bringing a drop of the reacting mixture on to a marble slab in contact with the above indicator. Absence of any red colour indicated the completion of titration. The estimation was repeated till concurrent results were obtained.

Results.—The results obtained are given in Table VI below and are also represented in Fig. 4. It is to be noticed that the rate of accumulation of reducing sugars in the berries is rather slow during the first 4 weeks after setting. During this period the rate of respiration is correspondingly very high. This means evidently that the amount of sugars produced by the plant in its earlier stage is not very much in excess of what would be required for the respiration process. It is only after the metabolic activities come to a uniform rate that the accumulation of sugars occurs. At this time the amount of CO_2 given off by the berries also shows a decline and practically becomes constant after a few days more.

TABLE VI.

Showing percentage of reducing sugars expressed on dry weight of berries, throughout their life cycle.

Jaishi			Tur		
Date of estimation	Age of berries in days	Percentage of reducing sugars	Date of estimation	Age of berries in days	Percentage of reducing sugars
20th April 1929 .	2	·95	28th April 1929 .	5	1·24
23rd April 1929 .	10	3·65	3rd May 1929 .	15	4·39
27th April 1929 .	20	7·83	10th May 1929 .	19	7·62
8th May 1929 .	26	9·07	20th May 1929 .	29	9·00
16th May 1929 .	35	17·98	27th May 1929 .	36	15·22
23rd May 1929 .	40	23·06	3rd June 1929 .	40	54·55
30th May 1929 .	47	46·12	10th June 1929 .	50	88·41
6th June 1929 .	56	66·76	17th June 1929 .	55	94·74
13th June 1929 .	60	88·00			
20th June 1929 .	67	92·56			
26th June 1929 .	75	93·31			

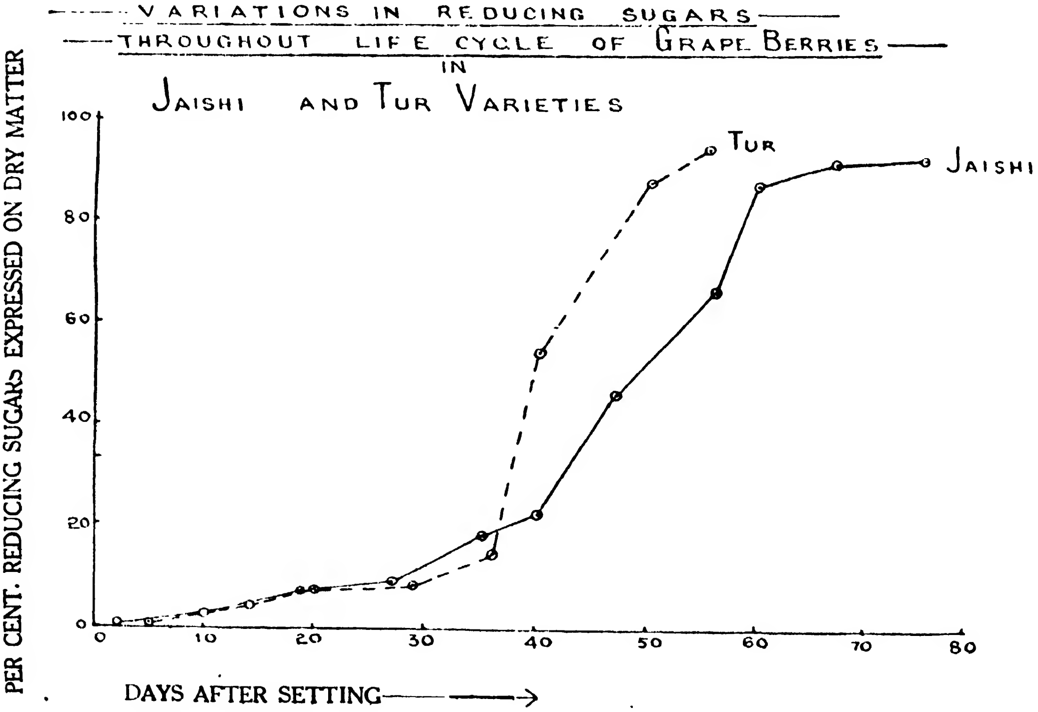

Fig. 4.

3. *Estimation of total titrable acids.*—Lewis [1927] has shown that the acids present in grapes consist mostly of tartaric and malic acids. The unclarified juice as prepared above was used for the estimation of these acids. This was done by titrating against $\frac{N}{10}$ NaOH using phenolphthalein as indicator. Duplicate titrations being always carried out. The results obtained were expressed in terms of malic acid.

Results.—Table VII and Fig. 5 illustrate that the total titrable acids also increase during the first 4 weeks or so and then in parallel with the rise of reducing sugars, they begin to decline gradually. The decrease in the quantity of acids continues up to the end, when only about three per cent. of them are present on the 75th day in *jaishi* and 55th day in *tur.* The presence of such a small amount of acid in perfectly ripe berries obviously constitutes an advantage as far as its flavour and taste are concerned.

TABLE VII.

Showing the percentage of total titrable acids expressed in terms of malic acid on dry weight of berries.

Jaishi			*Tur*		
Date of estimation	Age of berries in days	Percentage of malic acid	Date of estimation	Age of berries in days	Percentage of malic acid
20th April 1929 .	2	14·46	28th April 1929 .	5	17·36
23rd April 1929 .	10	18·23	3rd May 1929 .	15	21·10
27th April 1929 .	20	27·60	10th May 1929 .	19	23·23
8th May 1929 .	26	30·0	20th May 1929 .	29	24·86
16th May 1929 .	35	36·98	27th May 1929 .	36	23·89
23rd May 1929 .	40	29·88	3rd June 1929 .	40	11·96
30th May 1929 .	47	16·84	10th June 1929 .	50	8·17
6th June 1929 .	56	10·90	17th June 1929 .	55	3·12
13th June 1929 .	60	6·46			
20th June 1929 .	67	4·35			
26th June 1929 .	75	3·27			

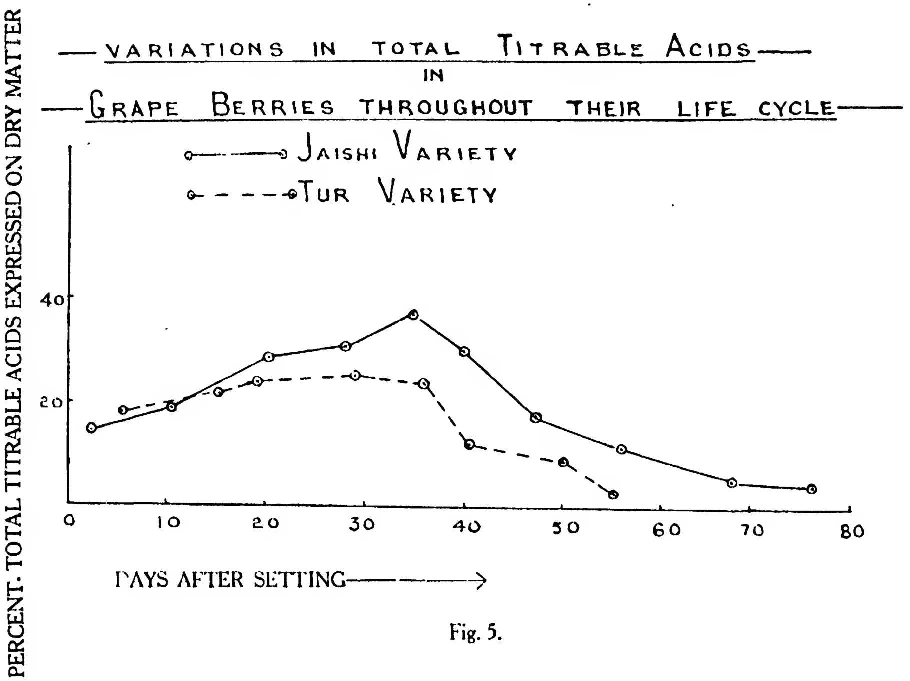

Fig. 5.

4. *Nitrogen.*- Nitrogen was estimated according to Kjeldahl's method. A weighed amount of berries generally 20 – 25 grams was transferred to Kjeldahl's flask and after the addition of 25 c.c. of concentrated H_2SO_4 and 10 grams of K_2SO_4 and a small crystal of $CuSO_4$, the whole was digested over a strong flame till the solution became quite transparent.

The contents on cooling were transferred to 500 c.c. flask and made up to the required volume. 50 c.c. of this solution were added to a distillation flask and strong soda solution added till the liquid became distinctly alkaline and ammonia liberated was received in 20 c.c. of $\frac{N}{10}$ NaOH and thus the amount of H_2SO_4 used and consequently the amount of nitrogen present in the corresponding sample was calculated, from which the percentage of nitrogen in dry weight of berries was arrived at. In order to allow for the amount of nitrogen present in the different reagents a control was always run parallel to the experimental flask.

Results.--The determinations were made 4 times during the life cycle of berries in *jaishi* only. The results obtained are given in Table VIII which show that nitrogen falls down consistently up to the 47th day, while on 75th day there is a slight rise of which no satisfactoy explanation can be offered.

TABLE VIII.

Showing the percentage of nitrogen in grape berries expressed on dry weight at different times.

Variety	Date of estimation	Age of berries in days	Percentage of nitrogen
Jaishi	18th April 1929	5	2·41
	2nd May 1929	19	1·44
	30th May 1929	47	·536
	26th June 1929	75	1·11

5. *Water-insoluble Residue.*—Sugars and acids are the chief water soluble constituents in grape berries. A great deal of cellulose, proteins and other material insoluble in water are also present. The amount of these was determined by taking a known weight of berries and grinding thoroughly in a pestle-mortar till it was reduced to a fine pulp. This pulp was now repeatedly washed with distilled water to free it of all the soluble substances. Insoluble residue was dried in a steam oven to a constant weight.

Results.—Water-insoluble residue was found practically constant during the entire life cycle of the berries. It came to 4·73, 3·64 and 3·41 per cent. of the weight of fresh berries. It has been observed that total organic nitrogen shows a gradual decline. This would mean that this decline is rather restricted to the soluble portion of the nitrogen showing thereby that the metabolic processes during the growth and maturity of the berries make use of soluble and hence rapidly available nitrogenous substances.

6. *Specific gravity.*—The determination of specific gravity was made with the object of finding out the changes in the concentration of the juice during the ripening period of the berries. The juice was extracted as previously explained and filtered through 4 or 5 layers of fine muslin. Specific gravity was determined by actual weighing of the juice in a specific gravity bottle.

Results.—The analytical data obtained are shown in Table IX. The figures for specific gravity show a steady rise throughout the life-cycle, showing that the amount of soluble matter goes on increasing till the end. It is remarkable that

this increase runs almost parallel with the increase in reducing sugars, showing thereby that the amount of soluble material consists mainly of reducing sugars.

TABLE IX.

Showing the specific gravity of grape juice in Jaishi *variety.*

Date of estimation	Age of berries in days	Specific gravity of the juice
24th April 1929	12	1 0190
2nd May 1929	17	1·0192
9th May 1929	26	1·0198
16th May 1929	33	1·0239
23rd May 1929	40	1·0304
30th May 1929	47	1·0492
7th June 1929	54	1·0587
14th June 1929	61	1·0643
21st June 1929	68	1·0795
28th June 1929	75	1·0990

7. *Cellulose*.- This constituent was not determined directly but some idea can be obtained by subtracting from the figures for water-insoluble residue the corresponding amount of insoluble proteins as calculated on the nitrogen basis. The figures for nitrogen are arbitrarily multiplied by the factor 6·25 to get the proteins. The results are given below in Table X.

TABLE X.

Showing the percentage of cellulose in grape berries at different ages as calculated from water-insoluble residue and protein, etc.

Date of estimate.	Age of berriers in days	Percentage of nitrogen.	Percentage of total solids	Percentage of total proteins as calculated from nitrogen	Water-insoluble residue	Percentage of cellulose
18th April 1929	5	2·41	13·75	2·069	4·73	2 661
2nd May 1929	19	1·44	6·93	·619	3·29	2 671
30th May 1929	47	·536	10·47	·35	3·08	2·730
4th June 1929	75	1·115	20·0	1·394	3·41	2·016

It will be seen that the percentage of cellulose in the berries is unaffected by other changes that take place during the life-cycle of the fruit. The conclusion seems to throw some light on the cellulose constitution of the berries. The size of the berries increases and yet the amount of cellulose remains almost constant. Does this mean that the material comprising the cellulose is of an elastic nature, and in its distended form can serve the needs of the berries as well, as in the earlier stages of growth of the fruit ? The question requires further investigation.

Discussion of the results.

As already remarked there is a distinct correlation between the respiratory process going on in the berries and the amount of sugars and acids present there.

A statistical study of correlation (1) between respiratory activity of the berries and reducing sugars in the case of *jaishi* shows that it is fairly significant and the co-efficient of correlation comes to $-\cdot 52 \pm \cdot 14$. This evidently means that the increase in reducing sugars tends to lower the respiratory activity of the fruit and (2) between reducing sugars and total titrable acids indicates that the relationship is significant. Co-efficient of correlation in the case of *jaishi* is $-\cdot 078 \pm \cdot 08$ and in the case of *tur* it is $0 \cdot 92 \pm \cdot 03$. Respiration takes place to a great extent at the expense of soluble protein bodies. This means that the berries during their early period of growth make use of both sugars and proteins. That the amount of CO_2 given out by the berries after 4 or 5 weeks becomes almost constant points to the conclusion that henceforward the berries are functioning for the purpose of storing the products of photo-synthetic activity rather than meeting the demand involved during growth. The accumulation of sugars made after being saved in this way accounts for the economic importance of grapes.

The authors' thanks are due to Dr. Ramji Narain, Assistant to the Agricultural Chemist to Government, Punjab, for the help that he gave in carrying out the chemical part of the subject.

Summary.

1. Respiration rates of grape berries of *jaishi* and *tur* varieties were studied throughout their life-cycle. Experimental data show that the berries respired very actively during the early stages of their growth but the intensity of respiration slowed down as the berries advanced in age.

2. It appears that as ripening advances, there is an increase of sugars and a decline of respiration. Accumulation of sugars seems to retard respiratory activity, which is also affected by age.

3. Co-efficient of correlation between sugars and respiratory activity in the case of *jaishi* was worked out and was found to be significant. It came to $-\cdot 52 \pm \cdot 14$.

4. Rate of respiration in detached grape bunches as well as those in *situ* has been found to be the same and decreased as the process of ripening progressed. The results obtained are in exact conformity with those obtained by Kidd, West and Briggs.

5. Study of the respiration of berries during night time has not shown any noticeable difference, when compared with the results obtained during day time. Lower temperature seems to be responsible for the slight fall in the respiratory activity at night.

6. Reducing sugers show a steady increase with the ripening process. The maxima in the curve for sugar corresponds with the complete maturation of the grape berries.

7. Total titrable acids go on increasing for about four or five weeks and afterwards they begin to fall. The maxima in acid curve coincides with the accumulation of sugars in much greater amounts than before.

8. Nitrogen : Nitrogenous contents show a straight decline till 47th day.

9 Water-insoluble residue remains practically constant throughout the life cycle of the berries.

10. Specific gravity of the grape juice keeps a close pace with the increase of sugars.

11. Cellulose content of the berries remains stationary throughout, although several changes are taking place in other constituents.

12. Co-efficient of correlation between sugars and acids comes to $-0{\cdot}78 \pm 0{\cdot}08$ in the case of *jaishi* and $-0{\cdot}921 \pm {\cdot}03$ in the case of *tur*. It is found to be significant in both the cases.

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SOME OBSERVATIONS ON THE GROWTH OF *SESAMUM INDICUM*, D. C. IN DIFFERENT SOIL CONDITIONS WITH SPECIAL REFERENCE TO ROOT DEVELOPMENT.

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(With Plates LXVII and LXVIII.)

The importance of the relation of soil conditions to the development and distribution of root-systems is one of the chief considerations in the economic study of agricultural crops because it leads to an intelligent application to crop production.

In India, sesamum is grown in many different types of soil, from the poorest sandy soils to the richest clayey lands. It is but natural that the crop varies considerably in yield in the different soils. From the economic point of view, therefore, the different types of soil, which are most suitable for the full development of the crop, are worth investigating. With this idea two types of *Sesamum indicum*, Pusa Type 22 (early) and Pusa Type 29 (late) were sown in two series in different proportions of sand and clay. The plants were grown in large cylindrical containers made of wire-netting. These were lined inside thickly with plantain leaf-sheaths, and such pots were found to hold the soils very well. They were 15″ in diameter and 36″ deep.

The soils were prepared in the following proportions :—(*i*) clay*, (*ii*) $\frac{1}{4}$ sand+$\frac{3}{4}$ clay, (*iii*) $\frac{1}{2}$ sand+$\frac{1}{2}$ clay, (*iv*) $\frac{3}{4}$ sand+$\frac{1}{4}$ clay. Eight pots were used for each type thus allowing a duplicate set also running for observation. The soils were made uniformly moist, before filling in the containers, to provide the right condition for the germination of the seeds. As the sesamum crop is grown during the rains in Bihar very little irrigation was required ; when the soil became dry an equal amount of water was applied to each pot.

The roots of the early series were washed two months, and those of the late three months, after sowing. They were washed out slowly with a "Knapsack

* Clay, as ordinary paddy field soil, Pusa.

Sprayer", preserving at the same time the natural spread of the roots with the aid of long needles which were thrust in to keep the roots in their natural position when the soil was being washed away.

The detailed observations made on the root and shoot were as follows :—

(A) EARLY SERIES (TYPE 22).

Soil: Clay.—The plant grew to a height of 54 cm. with three secondary branches, and formed 4 capsules. The main root was 10 cm. long and was about 8 mm. thick at the start and then tapered gradually. There were 10 secondary roots; most of these were situated within a few cms. from the soil surface. The secondary roots produced very thin tertiary roots and these were about 6 per 1 cm. length. The spread of the roots in general was not extensive. The colour of the roots was rather dark brown.

Soil: $\frac{1}{4}$ sand + $\frac{3}{4}$ clay.—The plant grew to a height of 62 cm. with 4 secondary branches and formed 24 capsules. The main root was 12 cm. long and it was about 9 mm. thick at start and then tapered gradually. There were 14 secondary roots, most of them being within 5 cm. from the soil surface. The secondary roots produced thin but long tertiary roots and these were about 10 per 1 cm. length. The spread of the roots in general was comparatively greater than in the previous case.

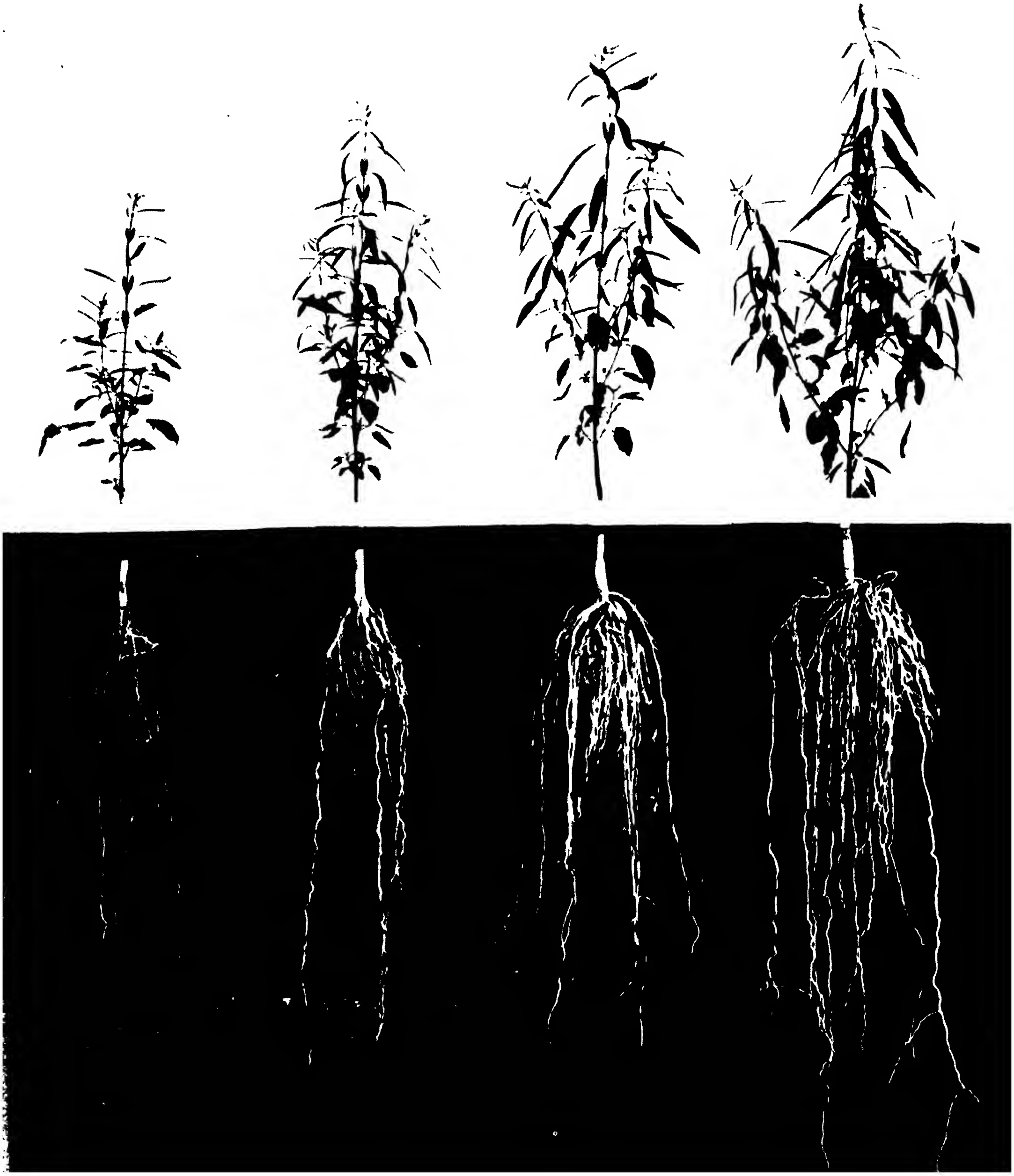
Soil: $\frac{1}{2}$ sand + $\frac{1}{2}$ clay.—The plant grew to a height of 72 cm. with 6 secondary branches and formed 128 capsules. The main root was 15 cm. long and it was about 10 mm. thick at start and then tapered gradually. There were 20 secondary roots, most of them being within 8 cm. from the soil surface. The secondary roots in this case were practically similar in proportions to those described above. The spread of the roots in general was greater than in the above cases.

Soil: $\frac{3}{4}$ sand + $\frac{1}{4}$ clay.—The plant grew to a height of 82 cm. with 5 secondary branches and formed 150 capsules. The main root was 18 cm. long and 12 mm. thick at start and tapered gradually. There were over 35 secondary roots; practically all of them appeared within 12 cm. from the soil surface. The secondary roots produced enormous number of long tertiary roots and they were about 15 per 1 cm. length. The spread of the roots was the greatest of all in this group. The growth of the roots and the shoots of the early series are illustrated in Plate LXVII.

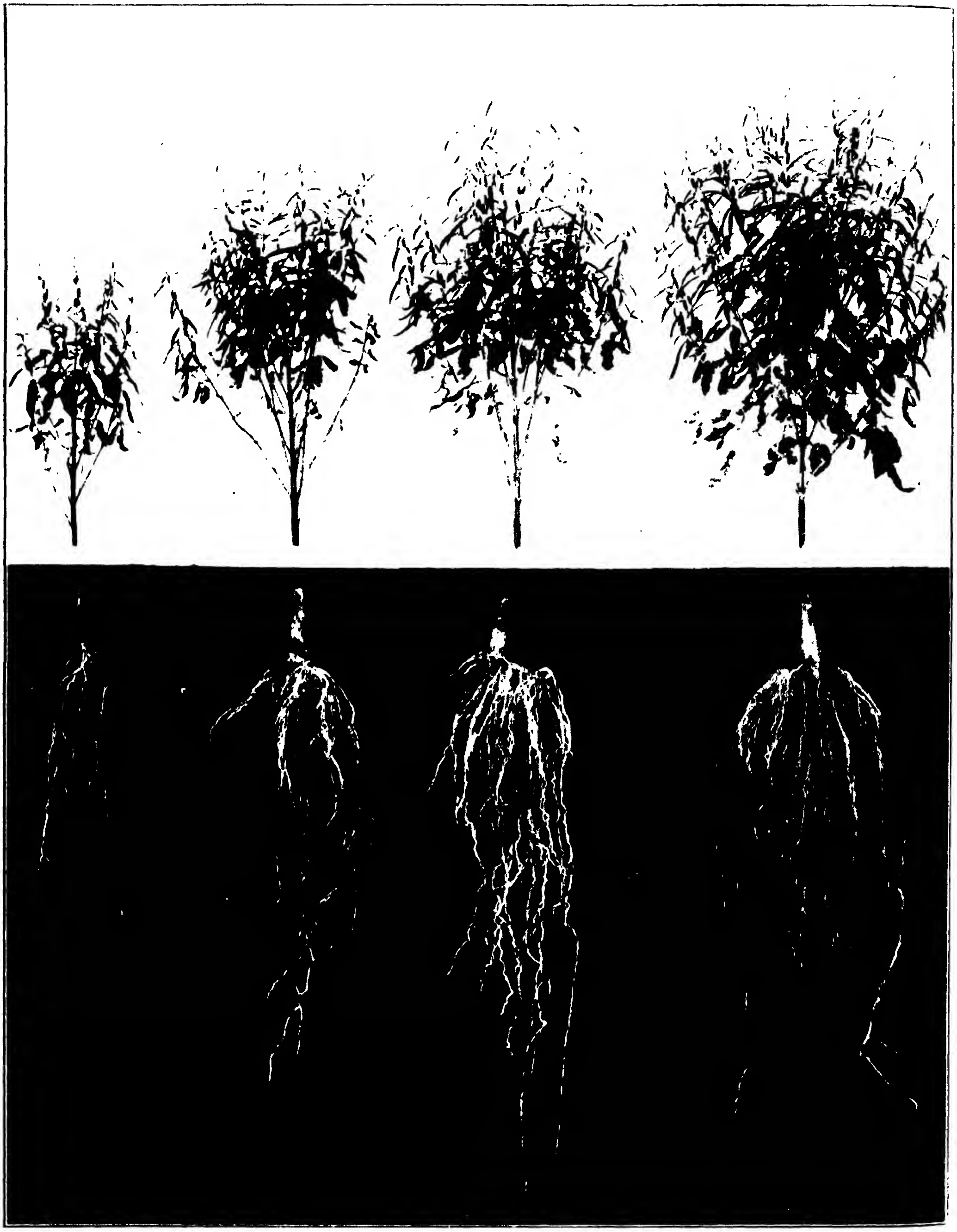
(B) LATE SERIES (TYPE 29).

Soil: clay.—The plant grew to a height of 64 cm. with 14 secondary branches and formed 48 capsules. The main root was 20 cm. long and it was about 1·2 cm.

EARLY SERIES TYPE 22.



LATE SERIES TYPE 29.



Clay. | $\frac{1}{4}$ Sand $\frac{3}{4}$ Clay. | $\frac{1}{2}$ Sand. $\frac{1}{2}$ Clay. | $\frac{3}{4}$ Sand. $\frac{1}{4}$ Clay.

thick at the start and then tapered gradually. There were 14 secondary roots most of them being within 8 cm. from the soil surface. The secondary roots produced thin and fairly long tertiary roots and these were about 3 per 1 cm. length. The tertiary roots also produced very thin short roots. The general spread of the roots was not much. The colour of the roots was rather dark.

Soil: $\frac{1}{4}$ *sand* + $\frac{3}{4}$ *clay*.—The plant grew to a height of 84 cm. with 18 secondary branches and formed 98 capsules. The main root was 50 cm. long and it was about 1·5 cm. thick at start and then tapered gradually. There were 17 secondary roots most of them being situated within 10 cm. from the soil surface. The secondary roots produced long, thin, tertiary roots and these were about 4 per 1 cm. length. The tertiary roots we·e longer than those in the previous case and possessed thin short roots. The general spread of the roots was comparatively greater than in the above case.

Soil: $\frac{1}{2}$ *sand*+ $\frac{1}{2}$ *clay*.—The plant grew to a height of 102 cm. with 20 secondary branches and formed 139 capsules. The main root was 55 cm. long and it was about 1·7 cm. thick at start and then tapered gradually. There were about 20 secondary roots, most of them being situated within 15 cm. from soil surface. The secondary roots produced thin, long, tertiary roots and they were about 6 per 1 cm. length. The tertiary roots produced thin long roots. The general spread of the roots was greater than that of the previous two cases.

Soil: $\frac{3}{4}$ *sand* + $\frac{1}{4}$ *clay*.—The plant grew to a height of 107 cm. with 22 secondary branches and formed 212 capsules. The main root was 60 cm. long and it was about 1·8 cm. thick at the start and then tapered gradually down to 15 cm. and was 5 mm. thick, down the entire length. There were more than 35 secondary roots, most of them being situated within 20 cm. from the soil surface. The secondary roots produced very long tertiary roots and they were about 10 per 1 cm. length. The tertiary roots also produced thin roots. The general spread of the root was the greatest of all in this group. The growth of the roots and the shoots of the late series are illustratad in Plate LXVIII.

From these observations and the accompanying photographs it is clear that as we proceed from the pot with clayey soil to the one with sandy soil, there is a marked increase of vigour which results in greater height, greater number of capsules, longer and thicker main root with accordingly well defined secondary and tertiary roots. The colour of the roots in the clayey soils is darker than the roots from the sandy soils. There is a definite correlation in growth and vigour between the root and the shoot. It is clear that the roots show their maximum development and distribution in the sandy soils. The growth in the soil with the largest proportion of sand is much better than in the other soils and hence we infer that sesamum prefers a light sandy soil with the necessary moisture for its maximum development.

SELECTED ARTICLE

THE SHEDDING OF NODULES BY BEANS.*

BY

J. K. WILSON.†

[Reprinted from the *Journal of the American Society of Agronomy*, Vol. 23, No. 8, August, 1931.]

Under uniform conditions nodules on leguminous plants probably remain as long as they are of any service to the plant. If growth conditions can accommodate a greater number, new nodules may develop. If adverse growth conditions are encountered after a period of favourable growth, nodules may be shed. Experiments have shown that with an increase in moisture there is an accompanying increase in nodulation until the plant has reached an equilibrium at this new moisture content with those symbiotic conditions that bring about nodulation. Little is known however, about what happens to a portion or all of the nodules that have developed under the best nodulating conditions when the plant encounters less favourable growth circumstances. It would seem logical that if an increase in moisture causes a plant to develop more nodules that the reverse condition should cause it to shed nodules. The observations recorded in this paper are of interest in this connection.

TECHNIC

The effect of a reduction in moisture content from that which was present when nodulation occurred was measured by observing the number and physical condition of nodules that remained on plants after they were subjected to various degrees of desiccation. The exact procedure of how such information was obtained is given in the following paragraphs.

Dunkirk silty clay loam was taken from a field where beans were growing. This was placed on a large canvas and uniformly mixed. Equal weights of the moist soil were put in one-half gallon crocks. The total weight was taken of each crock with the soil in it in order that moisture conditions could be controlled. A sample was also used for moisture determination. Calculations showed there were in each crock 1,860 grams of dry soil. With these facts at hand, it was possible to adjust the moisture content in any crock to any desired percentage.

In order to have uniform conditions for nodule formation, the soil in each crock was not only thoroughly inoculated with a water suspension of the proper

* Contribution from the Dept. of Agronomy, Cornell University, Ithaca, N. Y. Received for publication February 18, 1931.

† Professor of Soil Technology.

organism, but also was maintained at 20 per cent. moisture. The crocks were kept standing in running water so that temperature conditions for all would be alike. Frequent weighings, sometimes twice daily, and the addition of distilled water kept the moisture content reasonably uniform.

Red kidney beans were planted on July 22, about 10 to 12 for each crock. On August 14, inspection showed plants to be well-nodulated, giving an average of at least 30 nodules to the plant. At this period desiccation was begun. The crocks were divided into groups of four and the moisture spontaneously reduced to the following percentages: 20, 15, 12·5, 10 and 8. After the moisture reached the desired percentage it was maintained at this content for one day and then brought back to the original 20 per cent.

Shedding observations

Observations were made on September 9. The plants were just beginning to bloom. Those in crocks where the moisture had been reduced to 10 and 8 per cent. were showing the effects of such a treatment. The lower leaves were beginning to turn yellow and in some cases to fall off. After the plant roots were freed from soil by gently washing them with a stream of water they were examined. The physical condition and number of nodules that remained on plant roots which had been desiccated to the varying percentages of moisture were observed. The data, together with other notes that seem desirable, are shown in Table I.

Table I.

Effect of moisture reduction from that which was present when nodulation occurred on the number and the physical condition of the nodules on red kidney beans.

Percentage moisture reduced to	Number of nodules remaining on each plant	Affected nodules		Condition of affected nodules
		Number	Per cent.	
20*	35, 13, 53, 14, 78, 43, 54, 25, 61, 90, 51, 84, 58, 72, 106, 113, 86, 101, 101, 112, 110.	None	None	
15	75, 64, 89, 82, 130, 32, 39, 18, 28, 35, 23, 60, 48, 57, 72, 50, 84, 44, 42, 38.	11, 20, 11 . .	0·04	Soft and float on water.
12·5	48, 47, 72, 46, 80, 52, 112, 51, 49, 43, 85, 50, 89, 54, 36.	26, 26, 28, 15, 46, 22, 35, 15, 19, 18, 44, 35, 50, 33, 20.	36·00	Soft and float on water. Some hollow, some very brown.

* Present when nodulation occurred.

TABLE I—*contd.*

Percentage moisture reduced to	Number of nodules remaining on each plant	Affected nodules		Condition of affected nodules
		Number	Per cent.	
10	35, 55, 66, 57, 52, 34, 25, 52, 109, 44, 29, 24, 53, 46, 70, 34, 70, 30, 70, 9, 17.	0, 0, 0, 20, 14, 15, 8, 0, 18, 9, 0, 0, 13, 0, 0, 0, 17, 16, 24, 6, 12.	15·00	Soft and float on water; none hollow; 24 dislodged from plant roots and dark.
	33, 44, 79, 57, 21, 50, 103, 50, 41, 30, 41, 64, 104, 65, 11, 39, 55, 23, 89, 29, 48, 38, 19, 28.	Not determinable.	..	About 50 floaters; some badly decayed; others un healthy but no visible signs of decay.

The records are typical of several such tests. They indicate clearly that a reduction in moisture of a few per cent. for 24 hours from that which was present when nodulation occurred resulted in a shedding of nodules. A drop in moisture from 20 to 12·5 per cent. destructively affected 432 of 1,346 nodules. This was over 36 per cent. Individual plants showed as high as 57 per cent. of the nodules to be affected. Some of the affected nodules were light enough to float on water, some were soft, while all that was left of others was an empty hull. The latter were characterized by a brown or dark color. Many of those that were not visibly affected were undoubtedly less vigorous and of reduced value to the plant.

Many of the nodules recorded in the table as remaining on plants at harvest time were in reality some that had developed between the end of the desiccation period and harvest time. This was judged partly from the small size and fresh appearance which they exhibited and partly from the average number of nodules on plants when desiccation was started in comparison with those present at harvest time on plants constantly kept at a uniform moisture content. Shedding of nodules occurred more readily on the small and fibrous roots than on the tap root or from locations near the tap root. The mechanism by which the nodules were shed was not observed. There was no evidence that the contraction of the soil during desiccation took part in the process. Most of the nodules affected were still in contact with the root, and decay seemed to begin on the inside of the nodule. In a similar experiment a drop in moisture from 25 to 20 per cent. also caused a similar shedding of nodules.

It required a considerably longer time to desiccate the soil to 10 or 8 per cent. moisture than to 15 or 12·5 per cent. This means that those plants which grew

in soils desiccated to 10 or 8 per cent. had a shorter time for the decay of affected nodules, before being examined than did those plants which grew in soil desiccated to 15 and 12·5 per cent. moisture. This made it difficult to determine how many of the nodules were affected and may account for the observed condition of nodules on those plants from crocks where the moisture was reduced to 10 and 8 per cent.

Discussion

These results offer a reasonable explanation for the failure of numerous investigators to obtain beneficial results from artificial cultures, particularly on beans, and suggest why such cultures may sometimes reduce bean-yields. Once a plant has formed numerous nodules, as is often the case in wet soil in early spring, and subsequently encounters a dry period before maturity, it may shed many nodules. When the moisture is again increased new infections occur. This process of nodulation and shedding of nodules, in various degrees of completeness, may happen several times during the life of the plant. The effect of such recurring nodulation and its resulting intermittent service to the plant may stunt it so badly that final growth may be considerably less. Early growth in the presence of high moisture with accompanying stimulated nodule production brought about by the use of artificial cultures may produce a plant that canno readily adjust itself to drastic moisture changes which may often occur before plant maturity.

These findings also aid in the interpretation of many conflicting data, particularly those relating to nodular counts on plants at or near blooming time. Such data are without question subject to considerable experimental error and should not be given too much credence unless one knows the moisture conditions to which the plants have been subjected before the observations are made.

Although the observations presented were made on young bean plants, there seems to be no reason why the effect of desiccation on nodules should not apply to many other legumes.

Conclusion

Plants were grown in soil whose moisture content was controlled. After nodulation had occurred the moisture content of the soil was reduced to definite values for 24 hours and the effect on the existing nodules observed. The outstanding observations are listed below.

A reduction of soil moisture from 20 to 12·5 per cent. caused bean roots to shed on the average about 36 per cent. of their nodules. Some individual plants showed 57 per cent. of their nodules to be destructively affected by this drop in moisture. Shedding occurred more freely on small and fibrous roots than on larger roots.

ABSTRACTS

Fauna of Lahore. 1-Butterflies of Lahore. D. R. PURI. *Bull. Dept. Zool. Punjab University.* Vol. I, pp. 1—61, [Coloured Plates I—IV, biblography 94] April 1931.

A systematic account of 57 species of butterflies collected from Lahore, mainly during the summer of 1925, is given. Keys to genera and species have been added. A number of the species mentioned are of economic importance as pests of crops. [M. A. H.

Agricultural Meteorology of Indo-China [trans. title]. P. CARTON (*Agr. Prat. Pays Chauds, n. ser., 2 (1931), No. 9, pp. 199—209, figs. 4*). [Extracted from the Experiment Station Record, U. S. A. Department of Agriculture, Vol. 64, No. 9, June 1931].

The Bureau of Climatology and Agricultural Meteorology, organized in 1926 in the Meteorological Service of Indo-China, is described. The bureau receives data from 26 meteorological stations, 65 climatological stations, and 354 rainfall stations. Its work is confined to studies in climatology and agricultural ecology, in which it has the collaboration of specialists in coffee, tea, rubber, sugarcane, cinchona, and other economic plants, and of directors of experiment stations and plantation owners, as well as of the agricultural hydraulic service especially in the study of evaporation and winds.

A Study of Factors Influencing Inoculation Experiments with Azotobacter P. L. GAINEY. (*Kansas Sta. Tech. Bul.*, 26 (1930), pp. 66). [Extracted from the Experiment Station Record U. S. A. Dept. Agri., Vol. 64, No. 9, June 1931].

The natural distribution of Azotobacter was found 'very closely associated with, if not dependent upon, the absolute reaction of the soil'. It was further observed that when bacteria of this genus are introduced into cultivated acid soils with a pH of less than 6·0 they soon perish, the rapidity of this disappearance depending upon the degree of acidity.

'The addition of basic substances such as $CaCO_3$, $MgCO_3$ or neutral of basic soil in sufficient quantities to reduce the H^+ concentration to less than 10^{-6} will render acid soils a fit pabulum for the existence of Azotobacter. The addition of sufficient quantities of acid to a soil containing Azotobacter to maintain permanently a H^+ concentration greater than 1×10^{-6} in the soil solution will result in the disappearance of Azotobacter therefrom. The maximum H^+ concentration in the soil solution compatible with the existence therein of an active Azotobacter flora is very near 1×10^{-6}. The major factor controlling the existence of Azotobacter in soils, at least as so far determined, is the hydrogen-ion concentration of the soil solution, the hydrogen-ions apparently acting directly as a toxic agent, though there is a possibility that they may act indirectly by affecting some other soil constituent.'

Midrib Forking in Sorghum.—G. N. RANGASWAMI AYYANGAR and P. SUBRAMANYAM. *Madras Agri. Jour.*, Vol. XVIII, (1930), No. 10, pp. 526—529; 1 fig; 6 tabs.

The midribs of certain sorghum plants were found to bifurcate. The forking varied with the number of plants in which it is manifested in each line, the number of leaves in which the forking appeared and in the intensity of forking. The number of such plants varied from an odd plant to half the population. The behaviour in inheritance of the character was pursued. Midrib dichotomy is regarded as an ancestral feature. It may also have a bearing on the Ranalian origin of the Monocotyledons. [G. N. R.]

Polyembryony in *Elusine Coracana* (Gaertn), *Ragi*. G. N. RANGASWAMI AYYANGAR and N. KRISHNASWAMI. *Madras Agri. Jour.*, Volume XVIII (1930), No. 12, pages 593-595.

The occurrence of Polyembryony in *Ragi* has been recorded for the first time. True Polyembryony is rather rare among cereals. A microscopical examination was made, but from the nature of the material it was not possible to determine the manner of origin of the second embryo.

Current theories of Polyembryony are shortly reviewed and the view that, Polyembryony is an ancestral feature, reminiscent of the Gymnosperms is supported. The role of hybridity is considered to be that of bringing out the reversion by altering the normal tenor of the plant's life.

Sixteen references to literature have been cited. [G. N. R.]

Sorghum-studies in sowing depths. G. N. RANGASWAMI AYYANGAR and K. KUNHI KRISHNAN NAMBIYAR. *Madras Agri. Jour.*, Volume XIX (1931), No. 5, 3 figs.

Sowing depth in sorghum varies with soil and moisture conditions. Successful germination is due to the combined effort of mesocotyl and coleoptile. This combined length is a varietal character and is elastic within limits. Appreciable differences are noticeable within strains. This aspect of a strain will have to be remembered in its evolution. [G. N. R.]

A study of the Chemistry of Indian Buffalo milk Casein. R. B. GODE and D. L. SAHASRABUDDHE. *Jour. Central Bureau Ani. Husbandry and Dairying in India*, Volume III, part I, April 1929 and part II, July 1929.

After discussing the various methods of preparing fat-free and ash-free casein the most suitable method found by actual experiments is described. The ultimate analysis of buffalo casein done is compared with English cow casein. The former contains more of carbon and less of nitrogen than the latter.

The results obtained in the estimation of the di-amino acids in the hydrolytic products of buffalo casein by hydrochloric acid show that amid nitrogen is extremely low when compared with that in the hydrolytic products of cow casein, humin is much higher than in cow casein, corresponding to the decrease in the amid nitrogen there is an increase in the non-amino nitrogen, the quantity of cystine is negligible in buffalo casein while arginine, histidine and lysine and amino acids are practically the same in both the caseins. The action of pepsin and trypsin on buffalo casein shows that this casein is more difficult to digest than the cow casein. [D. L. S.]

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ORIGINAL ARTICLES

NEUTRALIZATION AND PASTEURIZATION OF SOUR CREAM CARRIED OUT AT THE BANGALORE INSTITUTE.

BY

S. COX,

Superintendent, Government Creamery, Anand.

Gujarat is the most important butter producing tract in India. Most of the butter is made from un-Pasteurized cream which in its journey from the villages where it has been separated becomes sour. Butter made from Pasteurized cream with high acidity at the time of Pasteurization is oily and objectionable to taste, and in order to overcome this defect neutralization of the acidity prior to Pasteurizing is necessary.

Hunziker, the expert on this subject, has shown that when a sufficient amount of lime is added to sour cream to reduce the acidity to ·25 per cent., the standard of acidity for churning cream, the lime fails to accomplish to the full extent this acid reduction. He proved, however, that the deficiency of the neutralizing action of the lime was due to physical and mechanical combination between the portions of insoluble lime and curd. The fact that 16 to 20 per cent. of the lime does not react in the cream must therefore be attributed to the great affinity of lime for casein. In this way lime so held is unable to exert its full neutralizing action. Hunziker suggests the use of 20 per cent. more lime in every case than shown by the initial acidity test.

The following table shows some of his results :—

TABLE I.

Vat No.	Acidity in cream		Lime not acting
	Before neutralization	After Pasteurization	
			Per cent.
1	·59	·30	14·7
2	·59	·32	20·6
3	·63	·32	18·4

TABLE I—*contd.*

Vat No.	Acidity in cream		Lime not acting
	Before neutralization	After Pasteurization	
4	·65	·33	19·0
5	·67	·33	15·9
6	·69	·32	15·9
7	·71	·32	15·2
8	·75	·30	10·0
9	·75	·35	20·0
10	·77	·33	15·4
11	·85	·37	20·0
12	·85	·33	12·0
13	·99	·34	13·3
14	1·00	·35	13·3

An examination of the above table reveals the fact that the percentage of the activity of the lime varied very much even when the percentage of acidity was the same as in Vats 1 and 2, 8 and 9, 11 and 12, 13 and 14. So 20 per cent. more added in the case of Vats 1, 8, 12, 13, 14 would have more than neutralized the cream and affected the quality and texture of the butter. The quality of trade cream in India is not up to the standard used by Hunziker. If this neutralization was not a straightforward operation, it is sure to be more difficult in India. To study the question, experiments were carried out under the guidance of Mr. F. J. Warth, M.Sc., Physiological Chemist to Government, and with the aid of Mr. Mumtaz Hussain, B.Ag., of the Punjab Agricultural Department, at the Imperial Institute of Animal Husbandry and Dairying, Bangalore.

TABLE II.

Experimental Results.

Experiment No.	Initial acidity of cream un-Pasteurized.	Acidity after Pasteurization.	Acidity after adding lime to standardize		Acidity after adding 10 per cent. lime less than for standardization		CO_2 present in cream
			Pasteurized	un-Pasteurized	Pasteurized	un-Pasteurized	
1	·8077	·5894	·324	·448	·348	·460	·2183
2	·7560	·5679	·467	·492	·478	·499	·1881
3	·8070	·5460	·207	·410	·242	·461	·2610
4	·9255	·8748	·283	·315	·320	·525	·0507
5	·9607	·8190	·306	·365	·351	·427	·1417
6	·8595	·7101	·355	·407	·421	·452	·1494
7	·9022	·6470	·226	·249	·173*	·194*	·2550
8	·7460	·6900	·334	·411	·229*	·249*	·0560

* 20 per cent. excess lime added.

TABLE III.

Showing fall in acidity by Pasteurizaing and standardizing cream and by adding 20 per cent. excess of lime over the standardizing quantity.

Experiment No.	Initial acidity of cream un-Pasteurized	Pasteurized acidity	CO_2 present	Acidity after adding lime to standardize, *i.e.*, 25 per cent. and Pasteurized	Acidity after adding 20 per cent. excess lime and Pasteurized	Remarks
1	·555	·4792	·0758	·254	·229	
2	·634	·576	·058	·250	·233	
3	·688	·659	·0288	·390	·318	
4	·587	·567	·0202	·300	·215	
5	·650	·567	·0142	·248	·177	
6	·5782	·570	·0082	·314	·100*	* 30 per cent. excess lime added.
7	·600	·585	·015	·309	·219	
8	·441	·430	·0110	·362	·292	
9	·452	·452	..	·351	·283	
10	·506	·480	·0260	·252	·192	

Although the amount of CO_2 present in the cream as shown in the above table is not correlated with the activities of lime, it certainly is responsible for the variations in the activity, in addition to the combination of lime with casein. The amount of CO_2 present in cream to be standardized should always be taken into consideration when calculating the amount of lime required for standardization.

PROCESS ADOPTED.

All cream for Pasteurization and standardization was put into a Wizard Central Spiral Coil Pasteurizer, which was found ideal for the purpose.

TABLE IV.

Showing some of the results obtained by the above procedure.

Vat No.	Pasteurized acidity	Amount cream lbs.	Initial acidity un-Pasteurized	Experimental Figures: Standardized: Lime added	Experimental Figures: Standardized: Acidity obtained	Experimental Figures: 20 per cent. excess lime: Lime added	Experimental Figures: 20 per cent. excess lime: Acidity obtained	Calculated lime	Acidity obtained in vat after Pasteurization. Acidity required ·25
1	·479	30	·555	·229	·254	·274	·229	·238	·243
2	·576	20	·634	·384	·259	·460	·233	·325	·248
3	·567	40	·587	·337	·300	·404	·215	·365	·236
4	·452	75	·452	·202	·351	·242	·283	·250	·238
5	·570	302	·578	·321	·314	·385	·170	·300	·220
6	·659	278	·688	·430	·390	·516	·318	·582	·234
7	·430	298	·441	·191	362	·229	·292	·387	·216
8	·480	388	·506	·256	·252	·307	·192	·250	·255
9	·410	334	·414	·164	·343	·197	·330	·330	·243
10	·429	540	·430	·177	·353	·213	·317	·290	220
11	·530	455	·538	·265	·350	·318	·265	·320	·225
12	·540	477	·540	·263	·357	·316	·281	·329	·231
13	·520	345	·528	·278	·398	·334	·298	·460	·230
14	·440	361	·490	·240	·259	·280	·228	·250	·240
15	·480	370	·490	·240	·300	·280	·249	·285	·243
16	·715	510	·830	·432	·411	·518	·372	·483	·266
17	·638	529	·716	·401	·399	·481	·351	·459	·241
18	·732	499	·880	·455	·423	·546	·382	·581	·255
19	·584	508	·638	·391	·320	·469	·298	·468	·249
20	·777	482	·833	·481	·456	·577	·411	·612	·253

CONCLUSION.

Further experiments were carried out by me on the neutralization and Pasteurization of sour cream at Anand creamery, with the object of finding a simple formula ; but in each case the formula gave inaccurate results as the quantity

of casein in every vat of cream varied; this was due to adulteration of the cream with curd. As mentioned before there is a physical and mechanical combination between the portions of insoluble lime and curd and the curd always varies in purchased cream; therefore a correct formula is impossible. All the Bangalore experiments were carried out by us with the worst possible cream we could purchase. The butter manufactured from it was free from lime grittiness, of good aroma and texture. Samples were kept to find out its keeping qualities, and some tins opened 12 months after tinning were found to be of good quality. In Anand some creams were reduced to ·05 acidity, and the commercial starter added to the cream and churned at ·3 acidity; this butter in my opinion was nearly as good as butter made from fresh milk and the keeping quality was as good. The best lime procurable in India was used in these experiments.

The procedure shown above gave very accurate results after we had gained sufficient experience and could be used with great success by any one manufacturing about 150 lbs. of butter daily from purchased sour cream, as the experimental labour in the laboratory only takes up about half an hour and is very much more accurate than formulae. We found that the secret of our success was due largely to the method by which the milk lime was prepared. Further efforts are still being made by me to arrive at a simple formula which can be used by the usual type of butter-men we employ in India.

THE STATISTICAL BASIS OF THE TOTAL PRODUCTION OF A CROP.

BY

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INTRODUCTION.

It is of primary importance to an agricultural country like India that it should possess accurate agricultural statistics which would give at any time a reliable indication of the country's requirements of each agricultural commodity, its exportable surplus, if any, and its economic position as indicated by supply and demand. The improvement of statistics of agricultural production is therefore of the greatest importance. In India, frequently visited as it is by famines, accurate statistics of the yields of crops are needed in order that timely steps may be taken to avoid shortage of supplies during lean years, and to handle bumper crop without embarrassment and to the best advantage. A continuous supply of accurate statistical information is essential under modern conditions of marketing staple commodities. The forecasts of cotton and wheat, for example, issued by the United States of America, have such a potent influence upon world prices that even a suspicion of the reduction of yield of any of these crops at once reacts on their prices at Liverpool. But the case of India is striking in its own way—it is a continent with diverse climates, soils and crops, producing all its food crops primarily for its own requirements but usually possessing an important exportable margin and non-food crops, such as cotton and jute, largely for export, in addition to meeting the needs of Indian industries. If the Punjab and the United Provinces produce wheat in large quantities, Bengal, Bihar and Orissa, Madras and Burma are the chief producers of rice. Cotton is produced largely in five provinces, and jute is practically the monopoly of Bengal. Thus, apart from the important export trade, there is an enormous and evergrowing internal trade so that the need for accurate statistics of provincial agricultural production and exchanges is becoming more and more necessary.

THE PRESENT SYSTEM OF ISSUING FORECASTS.

The crop forecasts are estimates of production which are issued at suitable intervals in order that the markets in India and in importing countries may know

what each crop is likely to produce. Such information when timely and accurate discourages wild speculation and reduces the risk of market panics. The present method of forecasts may be summarised thus:—Three factors are brought in for framing an estimate of outturn, *viz., the acreage, the condition factor and the standard normal outturn per acre.* The condition factor represents the ratio of the current crop to a normal crop, and the normal yield per acre has been officially defined to be the average yield on average soil in a year of average character. Thus, with standard normal outturn per acre, with the condition factor expressed as the percentage of the normal, the product of these three factors gives the estimated yield of the crop. The reporting agency in the provinces is usually the revenue staff from the village accountant upwards, except in Bengal and some other permanently settled tracts where the absence of revenue staff necessitates less satisfactory arrangements.

Forecasts are now issued for ten crops on specified dates with the progress of the season, and they are as shown below :—

Crop	Number of forecasts	Date of publication of forecasts
Rice	Three	October, December, February.
Sugarcane	Do.	August, October, February.
Linseed	Do.	January, March, June.
Groundnut	Do.	August, October, February.
Sesamum	Four	September, October, January, April.
Wheat	Five	January, March, April, May, August.
Cotton	Do.	August, October, December, February, April.
Jute	Two	July, September.
Indigo	Do.	October, December.
Castor seed . . .	One	February.

The statistics of area and yield of the other crops are published in the Season and Crop Report issued annually by the provinces. The difference between the crops for which periodical forecasts are issued and those for which no such forecasts are published lies presumably in the importance of the former from the trade standpoint.

ACREAGE.

Of the three factors that enter into the computation of the estimated yield, the area figures as computed in India, except in permanently settled tracts like Bengal, are considered to be very accurate. But usually the area reported is the sown area, and a statistical estimate of how much of the sown area is harvested is necessary. There is again the important question of mixed crops, such as wheat and gram, wheat and barley, and wheat and rape seed; and different provinces have adopted different methods for calculating the equivalent area of each constituent of the mixture. Again in case of non-reporting areas or areas which report incorrectly, no systematic method has so far been devised to substitute correct figures or improve them. Though no hard and fast rule is possible in such cases, the officer in charge of these statistics can often estimate the area of a particular tract in any season with the help of the data of the previous season and the corresponding figures of the neighbouring similar tracts which have reported. If, for example, A reports X acres of cotton (or does not report at all), and if the adjoining tracts B and C report increases of a and b percentages over the previous season's area, a weighted average percentage increase of B and C may be taken to be a fair estimate of the increase of A over the last season's figure. Theoretically, the solution may be made more exact by increasing the number of adjoining tracts, provided they are identical with A in the matter of soil, weather, and other conditions that affect the acreage. As this proviso can seldom be satisfied, the best that the compiler can do is to detect gross errors and frame reasonable estimates to fill up the gaps.

THE CONDITION FACTOR.

The second variable that enters into the estimate of yield is the conditional or the seasonal factor by which an estimate is made regarding the current season in terms of the normal. The primary reporters report the yield as so many 'Annas' of a normal crop, and the weighted average of these is struck for the district and eventually for the province. The system of 'Anna estimates' is based upon the idea that yields should be expressed in sixteenths of the normal, and that as a rupee contains sixteen annas, a crop might be put down as so many 'Annas' crop. The original intention was that a 16 anna crop should represent the normal, but as it was found that village opinion regards a 16 anna crop as a first class crop, in most provinces the normal crop is now equated to 12 or 13 annas. Hence in interpreting these anna estimates a clear understanding is necessary between the reporting and the compiling agencies. The accuracy of this system obviously depends upon the intuitive skill of the primary reporting agency, firstly, in cor-

rectly picturing a normal crop, and secondly, in visualising a correct marking for the particular crop. But if the reported seasonal factors of a province for a sufficiently long series of years correctly represent the condition of the crop in those years, the average of those figures cannot differ appreciably from 100 representing the normal season. It has however been found that this is not the case, showing that the reported figures are not quite correct, and it has therefore been suggested that the seasonal factor as deduced from the anna estimates may be corrected by using the formula :—

The corrected seasonal factor

$$= \frac{\text{Uncorrected seasonal factor} \times 100}{\text{Average of the uncorrected for a series of years (usually 10 years).}}$$

But the whole problem reduces itself to how best we could rate the figures as reported at their proper value or, in other words, how best we could study the psychology of the reporting agency. But it must be pointed out that the grading itself of the anna estimates in most of the provinces is not sufficiently broad to secure a correct average. In Madras, for example, the grouping followed is 16 as. to 13 as., 12 as., 11 as. to 8 as., 7 as. to 4 as., and 3 as. to 0 as., with a 12 anna crop as the normal; and this is not broad enough and seems to be arbitrary. A better scale would be 16 as., 14 as., 12 as., 10 as., 8 as., 6 as., and 4 as. to 0 as.

With regard to the interpretation of the normal itself, instead of taking an arbitrary 12 as. (or any other figure) as equal to 100 per cent., the average anna yield (weighted for the area) for a long series of years may be taken to be the normal, and this will naturally vary with the progress of time. Again for correcting the seasonal factor, instead of taking the average uncorrected seasonal factor for a series of years for the denominator, it would be statistically correct to take the mode or the greatest uncorrected seasonal factor for a long series of years. But a detailed examination of the reported data for a long period is necessary to arrive at the best method of correcting the seasonal factor. However, a systematic examination of the anna estimates as reported from villages should be undertaken to secure uniformity and to remove wide discrepancies in reporting that are possible under the present system. If two neighbouring villages growing the same crop report widely differing anna estimates, the compiling agency may detect such errors and improve the data. In the case of non-reporting tracts, the anna estimates of the neighbouring homogeneous tracts may always be utilised to fill up the gaps. As the estimates of yield depend mainly upon the accuracy of these anna estimates, the statistical officer incharge of these returns may take samples of anna estimates for different villages growing the same crop of the same

age and examine them in light of any evidence that may be available, such as rainfall and temperature. Statistical methods of sampling may be employed fruitfully to discover gross errors in reporting, and in all such cases a revision of figures may be called for from the reporting agency itself. But a statistical intuition combined with systematic methods of examination is necessary on the part of the compiling staff before the data of the reporting agency are finally adopted.

STANDARD NORMAL OUTTURN.

The third factor which influences the estimates of outturn is the accuracy of the normal yield. The normal yield has been defined officially to be the average yield on average soil in a year of average character. Statistically, an analysis of the yields of a long series of years studied with all the factors that have influenced the yields may help to form an estimate of what is the normal crop. The Agricultural Department in each province classifies the lands into irrigated and unirrigated, and maintains standards of normal yield for different crops. Periodically these data are revised, and in most of the provinces this is done by a system of crop-cutting experiments under the supervision of responsible officers of the district staff or of the provincial Agricultural Department. But the average deduced from a few samples only implies that a sufficient number of samples is taken characteristic of the whole soil. The nature of the crop, the homogeneity of the area chosen, and the identity of the times of harvest are all factors that influence the accuracy of the average. Theoretically, the problem is how with different samples, say of the same size, their means are distributed; and the accuracy of the average would depend upon a sufficient number of samples having their means falling within a given range of the true mean. Notable work has been done in this direction by Mr. J. A. Hubback [1927] in sampling for rice yield in Bihar and Orissa. How best to secure an average from fields of hetrogeneous character is a problem full of complexity and the common methods of estimating it either from combining heaviest and thinnest crops, or from an intuitive selection of an average field, are obviously misleading to strike a correct average. As the experimenter is to make a selection from a large number of plots growing different varieties at different stages of growth, the method must be such that as far as possible the personal equation is eliminated. With this view, a large number of samples must be taken distributed regularly both *in time and space*.

Mr. Hubback's method of sampling is this:—A tract of 1,000 square miles is taken and a sufficient number of centres is fixed spread as evenly as possible over the area, one day being allotted for each centre, and the days being evenly

distributed over the period of harvest. The sampler goes along one direction and after circling round comes back to the original position so that he covers almost the same area on each day. 30 to 40 samples in a day of busy harvest and 10 to 20 a day when it is slack may ordinarily be secured. But from a statistical standpoint it is necessary that the number of centres and the number of samples should depend upon the extent of the tract and the area harvested. The randomness of the centres and the number of samples taken in each day would materially influence the resulting average. Theoretically, with a large number of samples the distribution of their means as indicated by their average and standard deviation may be studied to deduce in how many of the samples the means are close to the average. But it is usually assumed that the distribution of means of a large number of random samples is the normal law of error, and on this assumption the odds or the probability of a particular mean occurring can be deduced from normal law probability integral table . Mr. Hubback from the examination of his samples concludes that 'the mean yield of a harvested area of 1,000 square miles may be secured correct within one maund per acre in about 95 per cent. of cases of samples examined'. But it must be pointed out that the significance to be attached to a particular average depends upon the law of distribution of the means of the large number of samples taken which is not always normal. in which case the standard deviation would differ from that obtained from an assumption of the normal law. It is therefore necessary that the actual frequency of the samples should be examined before any inference is drawn.

SUGGESTIONS FOR VERIFYING THE FORECASTS.

Apart from rigorous tests that must be undertaken periodically to verify and improve the accuracy of these various factors that enter into the computation of the final yield, the final figures arrived at by any system of forecasts can always be subjected to a scrutiny by independent means. (*a*) If the statistics of the internal trade of a country combined with export and import figures should be available, the only other factor that would account for the total production would be consumption for which estimates might be worked out. But when the internal movement itself is not known, as is in India --such data are now available for raw cotton only---the chances of improving these statistics are minimised. If final estimates could be worked out for a series of years based upon trade returns and estimates of consumption, they could be utilised to check the forecasted figures with corrections if necessary by any index of the particular season. (*b*) Agricultural meteorology has been developed to a scientific pitch in recent times. In a country like India subjected to whims of Nature, the study of all meteorological

elements that influence the yield can be fruitfully undertaken. The effects of meteorological factors such as rainfall, direction and force of the wind, soil temperature and moisture content could be considered in verifying and improving the forecasts. Statistically the problem is one of multiple correlation, the correlation between the yield and the various heterogeneous factors producing a joint result. But the distribution of every one of these elements has to be recognised more than the total quantity during the year. For it is a common experience that continuous rain for a week accompanied by a break the next week has an effect upon the crops which is different from a continuous rain the two weeks together of the same quantity. Thus, in correlating the rainfall with the yield, it is not merely the actual values of the weekly or the daily results that matter but their serial character that counts. Interesting work has been done in India correlating rainfall and yield, notably by Mr. S. M. Jacob, I.C.S. [1916], who has established prediction formula of both sowings and yield of crop in the Punjab based upon rainfall data for thirty years. A recent publication has worked out detailed correlations between weather and crop with special reference to Punjab wheat, and while in the case of acreage the results are not very bad when compared with official forecasts, the yield forecasts based upon such reports are not very reliable. But apart from the need for the improvement of the technique which would give more accurate results correlating acreage and yield with the various meteorological factors, it is necessary that the effects of factors like prices, crop rotation, and plant development have to be studied conjointly, if any useful inferences should be drawn.

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EXPERIMENTS ON RATIONING OF SILAGE TO COWS.

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Object of experiment.

The primary object of the experiment was to determine the relative merits of high and low silage feeding to cows in milk. The value of silage as a fodder for cows in India is now fully recognized. On the other hand, there is little or no information available regarding the amount which should be fed. As the making and feeding of silage involve a considerable amount of expenditure, the question of an optimum ration has a distinct economic significance. The experiments to be described were undertaken to procure information on this point in the first place. At the same time it was proposed to determine the starch equivalent requirements for milk production.

Procedure.

Twenty-two freshly calved cows were paired, each pair being of the same breed and as nearly alike as possible in weight, age and milk yield. By separating these pairs one into each group two uniform and comparable groups were formed. The grouping of the animals is shown in the accompanying table.

* Names in alphabetical order.

TABLE I.

Statement showing the selection of the herd for the experiment.

Group A							Group B						
Serial No.	Cow	Breed	Live weight	Advancement of lactation		Milk yield	Serial No.	Cow	Breed	Live weight	Advancement of lactation		Milk yield
	No.		lbs.	M.	D.	lbs.		No.		lbs.	M.	D.	lbs.
1	997	½ Bred.	837	3	29	20·25	12	441	½ Bred.	746	4	26	20·00
2	829	½ Bred.	981	2	25	23·40	13	445	½ Bred.	659	2	3	19·95
3	444	X Bred.	637	3	10	16·40	14	173	¾ Bred.	735	3	0	16·30
4	100	Scindhi.	584	3	24	15·15	15	427	½ Bred.	606	1	23	14·10
5	68	Scindhi.	709	2	12	19·65	16	77	Scindhi.	675	2	9	18·30
6	110	Scindhi.	582	1	27	16·70	17	150	Scindhi.	609	2	1	17·25
7	419	½ Bred.	657	0	28	22·90	18	447	¾ Bred.	646	0	22	23·50
8	126	Scindhi.	602	2	10	14·35	19	170	Scindhi.	673	3	13	16·15
9	766	¾ Bred.	974	2	18	35·95	20	417	½ Bred.	863	1	26	34·60
10	425	½ Bred.	761	1	5	28·35	21	398	¾ Bred.	836	1	13	31·55
11	972	½ Bred.	864	2	23	25·10	22	372	¾ Bred.	1151	1	25	26·20
Average			744·4	2	16	21·65	Average			745·0	2	9	21·65

The intention was to feed Group A twice as much silage as Group B, namely, 44·08 and 22·01 lbs. per 1,000 lbs. live weight respectively. After a short time it was found that this difference could not be maintained. Group A would not eat as much as the ration table allowed. Nevertheless, Group A actually consumed much more than Group B and thus we have the results of two groups on high and low silage feeding respectively. *Ragi* straw was selected as the supplementary roughage. It was fed in excess and the daily consumption determined by weighing the residue.

The concentrate ration was based on the assumption that the animals procured their full maintenance ration from the coarse fodders. As these were somewhat poor in protein, each animal was given groundnut cake at the rate of 1·426 lbs. per 1,000 lbs. live weight to ensure an ample supply of protein for maintenance.

The following concentrate mixture was fed for milk production :—

Wheat bran	4·0
Gram husk	2·5
Groundnut cake	3·5
Total .	10·0

Half a pound of this mixture was allowed for every pound of milk produced. The mixture though bulky is not excessively so for animals yielding up to 20 lbs. of milk. The amount to be fed to each cow was determined weekly on her previous week's milk yield. Milk yields were determined at each milking, and milk analyses were carried out on three consecutive days at fortnightly intervals. The live weights of the animals were determined similarly on three consecutive days every fortnight.

One cow in Group A (No. 110) died of pneumonia after the experiment had been in progress for seven weeks. To balance the groups the corresponding cow in Group B (No. 150) was taken out of the experiment.

The following time-table shows the procedure employed in feeding :—

3-30 A.M.	Feeding half the day's concentrate which was weighed out on the previous evening into buckets and soaked over night.
3-30 A.M.	Milking.
4-00 A.M.	Feeding half the day's ration of silage.
5-00 A.M.	Silage residues removed. *Ragi* straw fed.
8-30 to 9-00 A.M.	*Ragi* straw removed. Animals let out in bare paddock with water troughs.
2-30 P.M.	Animals brought in. Feeding and milking exactly as above.
6-30 P.M.	Animals let out in bare paddock for the night.

Experimental Results.

1. *Sampling and Analyses of Foodstuffs.*—Sampling of foodstuffs for moisture determinations and analyses was done daily at the time of weighing. The dry food samples were collected for a week and weekly samples submitted. The silage samples were submitted daily immediately after collection. For calculation of dry matter consumption the weekly average moisture content was used in the case of dry fodder. For silage, the dry matter in the food and in the residue was determined daily.

Table II.

Statement showing the average dry matter percentage in concentrates and roughages.

Silage		*Ragi* straw		Wheat bran	Gram husk	Groundnut cake
Fed	Residue	Fed	Residue			
26·02	26·53	85·81	81·93	87·82	91·58	91·92

The following table shows the average chemical composition of the foodstuffs used :—

Table III.

Statement showing the chemical composition of feeds (on dry basis).

Name of feed	Ash	Crude protein	Fat	Crude fibre	N-free extract	Organic matter
Silage	12·522	7·569	2·123	35·342	42·444	87·478
Ragi straw	7·237	3·344	1·258	36·298	51·863	92·763
Groundnut cake . . .	5·786	49·813	8·395	8·755	27·251	94·214
Wheat bran . . .	5·175	16·381	3·577	12·150	62·717	94·825
Gram husk	4·775	5·581	1·013	49·650	38·981	95·225

The figures show that these materials were all of good average quality.

Using the method employed in the Nutrition Section, the following starch equivalent values have been assigned to these foodstuffs :—

Table IV.

Starch equivalent values per 100 lbs. dry matter.

Silage	*Ragi* straw	Groundnut cake	Wheat bran	Gram husk
27·7	37·2	75·0	51·6	38·1

2. *Food Consumption.*—The food consumption has been calculated from the daily records in kilos. of dry matter per head per week. The figures are given in the accompanying table.

TABLE V.

Statement showing the weekly consumption of dry matter per head in kg.

Week No.	Group A — Dry matter consumed in kg.				Group B — Dry matter consumed in kg.			
	Silage	*Ragi* Straw	Concentrates	Total	Silage	*Ragi* Straw	Concentrates	Total
1	25·593	14·320	34·603	74·516	13·474	23·482	33·504	70·460
2	23·126	17·106	33·468	73·700	12·011	24·992	32·592	69·595
3	20·665	15·846	32·570	69·081	11·946	21·236	32·248	65·430
4	24·230	15·927	31·648	71·805	13·628	22·767	31·853	68·248
5	23·665	15·324	30·632	69·621	15·399	21·096	30·976	67·471
6	23·569	15·032	29·924	68·525	14·453	20·639	30·124	65·216
7	22·021	15·822	29·310	67·153	13·387	22·441	29·386	65·214
8	26·716	14·311	29·229	70·256	15·204	21·433	29·587	66·224
9	21·719	17·176	28·735	67·630	13·100	22·804	29·672	65·576
10	24·533	16·177	27·386	68·096	13·648	22·574	29·024	65·246
11	24·453	16·712	25·576	66·741	14·477	22·874	27·324	64·675
12	24·066	17·190	25·592	66·848	14·425	23·536	27·218	65·179
13	21·243	16·966	24·579	62·788	13·591	21·717	25·941	61·249
14	21·317	16·812	23·780	61·909	14·122	21·419	25·344	60·885
Total	326·916	224·721	407·032	958·669	192·965	313·010	414·793	920·768

The most important point to note is that when a large excess of silage was fed the average animal could not consume more than 25·6 kg. (dry matter) per week. The average consumption under these conditions was found to be 23·3 kg. (dry matter) which amounts to about 29 lbs. fresh silage daily. It should be noted too that this consumption can only be attained if a wasteful excess is provided. The second point to note is that the higher silage rationing led to slightly

higher total food consumption, the figures being 68·5 and 65·7 for Groups A and B respectively. Thirdly, it has to be noted that the cows on the low silage ration made up for the deficiency almost completely by eating more *ragi* straw, the figures for *ragi* straw consumptions being 16·1 and 22·4 for Groups A and B respectively. Finally it has to be observed that there was a distinct fall in food consumption towards the end of the experiment in both groups. It is reasonable to attribute this to a decreased appetite consequent upon a fall in the milk yield.

Live Weight Increase.—The group average live weight for fortnightly periods is given in the accompanying table.

TABLE VI.

Statement showing the fortnightly live weights.

Fortnight No.	Group A	Group B
	lbs.	lbs.
Initial	744·4	745·0
1	764·1	755·6
2	778·8	762·7
3	776·3	765·3
4	784·2	772·9
5*	800·0*	789·0*
6	801·7	791·0
7	808·1	790·4

* The sudden increase at the fifth weighing is due to the fact that the small cow from each group was removed from the test.

Milk Yields.—The total fortnightly yield for each group is given in the accompanying table :—

TABLE VII.

Statement showing the fortnightly milk yield decline.

Fortnight No.	Group A		Group B	
	Milk	Decline	Milk	Decline
	lbs.	lbs.	lbs.	lbs.
1	3156·25	....	3088·75	....
2	2998·75	157·50	3006·00	82·75
3	2844·25	154·50	2873·75	132·25
4	2485·50	358·75	2585·75	288·25
5	2286·25	199·25	2469·00	116·50
6	2146·75	139·50	2306·50	162·50
7	1859·00	287·75	2086·00	220·50
Total	17776·75	1297·25	18415·50	1002·75

It appears from this table that Group B which received less silage, consumed slightly less food and made a smaller live weight increase, produced somewhat more milk than Group A. It is quite possible that over-feeding has caused greater fat and flesh formation. However, the difference in milk production between the two groups is less than 2 per cent. of the total produce and therefore cannot be considered very significant. It should be mentioned here that the sudden drop during the fourth period is due to the fact that one cow was eliminated from each group at this time.

Fat and Protein Content of Milk.—The total fat and protein yielded for fortnightly periods have been calculated from the fortnightly fat and nitrogen determinations. The yields for each group are given in the accompanying table :—

TABLE VIII.

Statement showing total fat and protein.

Fortnight No.	Group A		Group B	
	Fat	Protein	Fat	Protein
	lbs.	lbs.	lbs.	lbs.
1	122·41	85·781	117·54	82·969
2	116·19	79·338	113·56	77·438
3	108·04	76·269	107·83	74·725
4	102·42	70·100	101·56	65·556
5	96·66	64·681	95·79	68·800
6	90·46	60·569	96·14	65·013
7	78·45	54·200	86·92	59·250
Total	714·63	490·938	719·34	493·751

Summing up the yields for the entire experimental period, the following figures are obtained :—

TABLE IX.

Statement showing the percentage of fat and protein.

Group	Milk	Fat	Fat	Protein	Protein
	lbs.	lbs.	per cent.	lbs.	per cent.
A	17776·75	714·63	4·02	490·94	2·76
B	18415·50	719·34	3·90	493·75	2·68

There was apparently a slightly greater milk yield from Group B, but this is almost exactly set off by slightly lower percentages of fat and protein with the result that the yield of milk products from the two groups is almost identical.

SUBSIDIARY OBSERVATIONS.

TABLE X.

Statement showing the dry matter consumption per head per day for 1,000 lbs. body-weight.

Group	Dry matter consumed in roughages	Dry matter consumed in concentrates	Total dry matter consumed
	lbs.	lbs.	lbs.
A	15·8	11·7	27·5
B	14·8	12·0	26·8
Difference	1·0	—0·3	0·7

The average food consumption in this experiment was good. The best consumption was attained by cow No. 417, Group B, which consumed 32 lbs. dry matter per 1,000 lbs. live weight.

TABLE XI.

Statement showing the daily consumption of dry matter per 1,000 lbs. live weight for different breeds.

—	Sindhi	Cross-breds
No. of animals	7	15
Average live weight	656·5	829·1
Dry matter consumed in roughages, per 1,000 lbs. live weight.	15·6	15·1
Dry matter consumed in concentrates per 1,000 lbs. live weight.	11·1	12·3
Total dry matter lbs.	26·7	27·4

Apparent Starch Equivalents Required for Milk Production.—These calculations have been carried out according to the procedure employed in the Nutrition Section. The sum of the starch equivalents required for maintenance and live

weight increase was first calculated for each animal. Secondly, the starch equivalent value of the total ration consumed by each animal was calculated from the figures given in tables IV and V. The difference between these two figures evidently represents the starch equivalents utilised for milk production.

The totals for the two groups are given in the accompanying table.

TABLE XII.

Starch equivalents required for milk production.

Group	Starch equivalents required for live weight increase and maintenance	Starch equivalents consumed from ration	Balance for total milk yield	Total milk yield	Starch equivalents per pound milk
A	6217·7	9666·8	3449·1	17776·75	0·194
B	5778·5	9539·3	3760·8	18415·50	0·204

Mr. Warth has made the following remarks on these figures: "The number of animals used and the milk yield obtained were sufficient for making a fair estimate. The agreement between the two sets of figures supports this view. The important point to note is that the apparent starch equivalents required for milk production are far below the accepted value which would be ·25 instead of ·20 for this quality of milk. The starch equivalent values of the food-stuffs have therefore been seriously under-estimated in this experiment. The actual values given in Table IV cannot be far out. In this experiment, however, chaffed fodders were used and Kellner allows a considerable enhancement of starch equivalent values for chaffing. In the present case if the values for *ragi* straw and silage were increased from 27·7 and 37·3 to 34·0 and 44·0 respectively, increases which certainly do not exceed the allowances made by Kellner, the values obtained for milk in this experiment would come up to the accepted standard. There is little doubt that the economical milk production in this experiment has to be attributed to chaffing. Other experiments on the subject of chaffing, which is probably of great importance in India, are in progress at Bangalore."

SUMMARY.

An experiment has been carried out to test the relative merits of high and low silage feeding to cows in milk. Two groups of well-balanced cows were selected. Group A received as much silage as it could eat. The quantity worked out to

29·2 lbs. fresh silage per head per day. This consumption was attained by feeding an excess, which meant an appreciable amount of waste. Groub B on the lower ration consumed 17·2 lbs. a day. *Ragi* straw was given as a supplementary fodder. This was fed *ad lib* and the daily consumption determined. Concentrate was given in proportion to milk yield. The experiment showed that the cows receiving less silage consumed more straw, the total food consumed of the two groups being almost equalised by this circumstance. The main data are shown in the accompanying table.

Per day per head	Group A	Group B
Average food consumption, in lbs.	21·5	20·7
" live weight increase, in lbs.	0·50	0·25
" milk yield, in lbs.	17·2	17·9
" fat in milk, in lbs.	0·69	0·70
" protein in milk, in lbs.	0·48	0·48

This experiment shows that silage, which is expensive to make and feed, may be reduced to 17 lbs. per head if necessary without affecting the milk yield.

Subsidiary observations showed that milk was produced very economically in this experiment. This favourable result is attributed to the use of chaffed fodder.

ACKNOWLEDGMENTS.

We are indebted to Mr. Warth for suggesting this subject of enquiry and for guidance during the work. We also owe our thanks to the staff of the Physiological Chemist for the fodder analyses carried out for us.

A FEEDING EXPERIMENT TO COMPARE THE MERITS OF SINGLE AND MIXED FODDERS.

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OBJECT OF EXPERIMENT.

It is a general belief that mixing of fodders is advantageous. From a theoretical standpoint this view seems to be sound. The animal gets variety and is likely to maintain a better appetite on that score alone. Furthermore, there is every likelihood that the mineral and other deficiencies of one fodder will be balanced by the other fodder. The animal should be better nourished. One of the first indications of this improved efficiency of a mixed ration should be seen in food consumption. If there is an appreciable benefit in feeding mixed fodders, the consumption should be better than the mean consumption of the two fodders fed separately and growth should be better. The primary object of this experiment was to test these points on a mixed ration of hay and *ragi* straw.

PROCEDURE.

Twenty-one dairy heifers were selected for the work. After a preliminary feeding period of one month, during which time careful observations were made on the appetite and condition of each animal, they were divided into three groups, three animals at a time being matched and one placed in each group. Group A received *ragi* straw, Group C Bolarum hay and Group B a mixture of these two fodders. To control the consumption of the mixed fodder, the hay was fed in the morning and the straw in the afternoon. By regulating the quantities given it

* Names in alphabetical order

was possible to maintain roughly an equal consumption of each, while allowing roughage *ad lib.* In addition to the dry roughage fed *ad lib,* all the animals received :

(1) Fresh Guinea grass at the rate of 3 kg. per 400 lbs. live weight.

(2) Concentrate consisting of a mixture of equal parts of groundnut cake and wheat bran at the rate of 3 lbs. per 400 lbs. live weight. To this one oz. of salt was added daily.

The Guinea grass and concentrate were fed according to a special sliding scale adopted by the Nutrition Section, the ration being increased with, but not at the same rate as, the live weight. The live weights were determined daily and the rations were adjusted weekly in accordance with the average live weight for the previous week. The daily feeding was carried out according to the accompanying time-table.

Morning.

7-15 to 7-45	Weighing.
7-45 to 8-0	Feeding of half the concentrate soaked overnight.
8-0 to 8-30	Feeding of half the Guinea grass.
8-30 to 11-0	Feeding of roughages.
10-15 to 10-30	Watering the animals.
11-0 to 1-30 P.M.	Heifers let off for exercise in the paddock.

Evening.

1-30 to 2-0	Watering the heifers.
2-0 to 2-15	Feeding the remaining half of the concentrate soaked in the morning.
2-15 to 2-45	Feeding the remaining half of the Guinea grass.
2-45 to 6-0	Feeding of roughages.
4-15 to 4-30	Watering.
6-0 P.M.	Calves let off in the paddock overnight.

Samples of all foodstuffs were taken at the time of weighing; the Guinea grass samples were submitted daily immediately after collection. The dry fodder samples were collected for one week and a weekly sample submitted. Dry matter determinations and chemical analyses were carried out in the laboratory of the Physiological Chemist. The accompanying table shows the average chemical composition of the foodstuffs used.

Table I.

Composition of fodders fed to heifers during the feeding experiment.

—	Ash	Protein	Fat	Fibre	Nitrogen-free extract
Ragi straw	7·264	3·200	1·256	36·238	52·042
Bolarum hay	11·860	1·863	1·987	37·520	46·770
Guinea grass	12·643	7·775	2·803	35·966	40·813
Groundnut cake	5·860	49·775	8·325	8·829	27·211
Wheat bran	4·826	16.513	3·579	12·040	63·042

Experimental results.

Consumption of Coarse Fodder.—Table II shows the fodder consumption by each group.

Table II.

Daily average roughage consumption of the different groups-per head in lbs.

Weeks	Group A	Group B	Group C
1	6·88	7·20	7·75
2	6·44	6·71	7·36
3	6·31	7·12	7·86
4	6·74	7·34	7·65
5	6·88	7·26	8·40
6	6·62	7·46	8·32
7	6·85	7·85	8·15
8	6·55	7·80	8·01
9	6·66	8·09	8·15
10	6·76	7·59	7·82
11	6·38	7·73	8·05
12	6·47	7·87	8·04
13	6·43	8·01	8·46
14	6·71	8·03	8·35
Average	6·62	7·58	8·04

The figures are given in full to make it clear that there has been a consistent difference week by week. Group C has always eaten most, Group B an intermediate amount and Group A least. There is no doubt whatever that the animals can and do consume more hay than *ragi* straw. Palatability might be suggested as a reason for the marked difference. The mixed ration is disappointing. It is true that the consumption has been more than the mean of the hay and *ragi* straw groups, but the excess over the mean is trifling and quite insignificant from a practical point of view. It may be noted here that the figures in this table appear more unfavourable than they actually are owing to the failure of one animal. This fact is made clear from Table III in which the average weekly consumption of each animal is shown.

TABLE III.

Daily average roughage consumption of the different heifers of the three groups in lbs.

Group A		Group B		Group C	
Calf No.	Roughage	Calf No.	Roughage	Calf No.	Roughage
831	7·06	830	9·66	839	8·92
888	7·91	838	8·79	832	8·74
818	7·25	841	8·15	856	7·87
828	6·85	837	7·89	869	8·42
827	6·10	825	7·44	810	7·81
822	6·44	821	7·38	836	8·05
800	4·41	844	3·68	848	6·37

It will be noticed here that, of the last trio, the animal in Group B turned out a bad doer. The animal in Group A was not good either, while the animal in Group C did very well indeed, taking into account its age and size. The results of this trio have weighted the figures somewhat adversely for the mixed ration and the *ragi* straw groups. It is clear, however, that even if this trio were omitted, the relative positions of the groups would not be affected nor would the position of the mixed ration be materially improved. It has to be admitted that a mixed ration has shown no advantage in the matter of food consumption.

Total Food Consumption.—As Guinea grass and concentrate were strictly rationed according to live weight, the variations in total food consumption are due entirely to the variations in coarse fodder consumption, which has already been discussed. Figures for the total food consumption are briefly summarised in Table IV.

TABLE IV.

Daily average food consumption (in dry matter) of the different groups per head in lbs.

—	Roughage lbs.	Guinea grass lbs.	Concentrate lbs.	Total dry matter lbs.	REMARKS
Group A . . .	6·62	1·64	2·95	11·21	*Ragi* straw only.
Group B . . .	7·58	1·64	2·94	11·16	3·92 lbs. Bolarum hay and 3·65 lbs. *ragi* straw.
Group C . . .	8·04	1·64	2·95	12·62	Bolarum hay only.

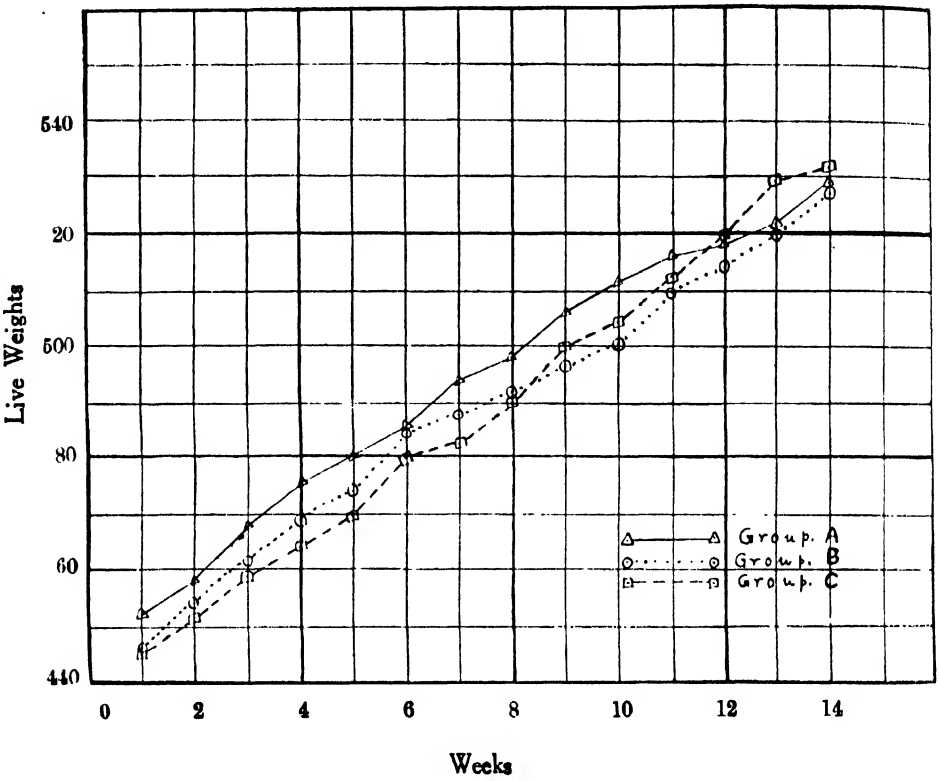
Live Weight Increase.—The weekly group average live weights are given in the accompanying table.

TABLE V.

Weekly group average live weights.

—	Group A	Group B	Group C	REMARKS
1st Week . .	452·0	447 0	446·0	
2nd „ . .	458·0	454·0	452·0	
3rd „ . .	468·0	462·0	459·0	
4th „ . .	475·0	469·0	464·0	
5th „ . .	480·0	474·0	470·0	
6th „ . .	485·0	484·0	480·0	
7th „ . .	494·0	488·0	483·0	
8th „ . .	498·0	492·0	490·0	
9th „ . .	506·0	497·0	500·0	
10th „ . .	512·0	501·0	504·0	
11th „ . .	516·0	510·0	513·0	
12th „ . .	517·0	515·0	519·0	One Calf of Group A was sick.
13th „ . .	522·0	520·0	529·0	
14th „ . .	529·0	527·0	532·0	
Live weight increase during the whole period.	77·0	80·0	86·0	

Small fluctuations may be observed, but on the whole there has been a steady and parallel increase in all the groups throughout the test. The increases are 77, 80 and 86 lbs., the differences between the three groups being scarcely significant. The changes in live weight are also shown graphically in the following Chart.



It is very clear from this graph that the three groups increased almost identically during the experiment. Group C seems to show a tendency to increase more rapidly towards the end. It is impossible to say whether this tendency is significant. It has to be concluded that during a test of 100 days the three groups were very similar in live weight increase.

Starch Equivalent Values of the Rations.—In the accompanying table the nutritive effect (starch equivalent required for maintenance *plus* live weight increase) is compared with the starch equivalent values of the rations which produced this effect.

TABLE VI.

Nutritive effect from live weights and starch equivalent consumption.

	Average live weights	Average live weight increment per day	Starch equivalent required per lb. live weight increment.	Starch equivalent required for increment of live weights	Starch equivalent required for maintenance	Nutritive effects from live weights	Starch equivalent value of rations fibre method	Excess of fibre method value over live weight value	Starch equivalent value of rations Kellner Graph	Excess of Kellner graphic method value over live weight value	American starch equivalent value of rations	Excess of American value over live weight value
Group A	494·0	0·786	2·0	1·572	3·750	5·322	4·755	—0·567	5·050	—0·272	5·662	0·340
„ B	489·0	0·816	2·0	1·632	3·700	5·332	4·885	—0·447	5·143	—0·189	5·777	0·445
„ C	489·0	0·878	2·0	1·756	3·700	5·456	4·817	—0·639	5·013	—0·443	5·627	0·171

The points to note are :—

1. The nutritive effect for the *ragi* straw ration is more nearly represented by the higher American values. In this experiment, however, the fodders were chaffed ; and if Kellner's allowance were made for the enhanced value due to chaffing, the European value for the *ragi* straw ration would roughly account for the observed nutritive effect.

2. The starch equivalent values assigned to *ragi* straw and hay are seen to be relatively correct. Absolutely they are both low, probably because no allowance has been made for the enhanced value due to chaffing.

Addendum by F. J. Warth.

Some time after this trial had been completed, the writer while engaged on a chemical examination of *ragi* straw, observed that this fodder when wetted absorbed an exceptionally large amount of water. The phenomenon was so striking that it could not be overlooked, but its significance might easily have been missed if the writer had not been given the privilege some months earlier of reading a Cambridge Diploma Thesis, by T. Y. Watson, in which it was shown that low consumption of beet pulp fodder was associated with a capacity which this fodder possessed of swelling on being wetted.

Accordingly the *ragi* straw and hay used in the feeding experiment were tested as follows :—10 grams of each were wetted with 100 c. c. of water and evacuated repeatedly under a pump until all air was expelled. The samples were transferred to measuring cylinders using further 50 c.c. of wash water. The total volume then stood at 156 c.c. in both vessels. The fodders having been freed of air settled rapidly, the *ragi* straw occupying a space of 90 c.c., the hay 65 c.c. only. On standing for a further period of four hours there was no change in these volumes.

This experiment shows clearly that on wetting *ragi* straw swells very much more than hay, and it seems probable that the low consumption of *ragi* straw in the feeding trial is connected with this property. The swelling of a material such as beet pulp might be expected, but that a straw should behave in this manner seems remarkable. This subject will receive further attention at Bangalore.

Summary and Conclusion.

An experiment has been carried out to determine whether mixed roughage is superior to single roughages. The test was made on three groups of heifers receiving respectively *ragi* straw, hay and a mixture of these two fodders. Concentrate and green fodder were fed to all alike.

It was found that the hay group consumed more fodder than *ragi* straw group.

The group on mixed fodder consumed scarcely more than the mean of the other two groups. Therefore, mixing of fodder has not yielded an appreciable advantage. In live weight increase during 100 days the three groups were similar, the increase per head being 77, 80 and 86 lbs. for the *ragi* straw, for the mixed ration and for the hay groups, respectively.

From starch equivalent calculations it was found that the values assigned to *ragi* straw and hay are correct relatively. Absolutely, the values are low, probably because no allowance was made for chaffing.

In the course of other work it has been observed that *ragi* straw swells considerably on wetting. Accordingly, the swelling of *ragi* straw and hay has been compared and it has been found that *ragi* straw swells very much more than hay. It would appear that the observed low consumption of *ragi* straw is related to this property.

Acknowledgments.

We are indebted to Mr. Warth for suggesting this subject of enquiry and for guidance during the work. We also owe our thanks to the staff of the Physiological Chemist for the fodder analyses carried out for us.

SELECTED ARTICLES

THE SCIENTIFIC WORLD-PICTURE OF TO-DAY.

BY

GENERAL THE RT. HON. J. C. SMUTS, P.C., C.H., F.R.S.,
President of the British Association.

Presidential Address Delivered in London on Sept. 23, 1931.

[Reprinted from *Nature*, Sept. 26, 1931.]

This Centenary Meeting of the British Association is a milestone which enables us to look back upon a hundred years of scientific progress such as has no parallel in history. It brings us to a point in the advance from which we can confidently look forward to fundamental solutions and discoveries in the near future which may transform the entire field of science. In this second and greater renaissance of the human spirit, this Association and its members have borne a foremost part, to which it would be impossible for me to do justice. I shall therefore not attempt to review the achievements of this century of science, but shall content myself with the simpler undertaking of giving a generalised composite impression of the present situation in science.

I am going to ask the question: What sort of world-picture is science leading to? Is science tending towards a definite scientific outlook on the universe, and how does it differ from the traditional outlook of commonsense?

The question is not without its interest. For our world-view is closely connected with our sense of ultimate values, our reading of the riddle of the universe, and of the meaning of life and of human destiny. Our scientific world-picture will draw its material from all the sciences. Among these, physical science will—in view of its revolutionary discoveries in recent years—be a most important source. But no less important will be the contribution of the biological sciences, with their clear revelation of organic structure and function as well as of organic evolution. Last, not least, the social and mental sciences will not only supply valuable material, but also especially methods of interpretation, insights into meanings and values, without which the perspectives of our world-picture would be hopelessly wrong.

Can we from some reunion or symposium of these sciences obtain a world-picture or synoptic view of the universe, based on observation and calculation, which are the instruments of science, but reaching beyond the particular phenomena which are its immediate field to a conception of the universe as a whole ?

That was how science began—in the attempt to find some simple substances or elements to which the complex world of phenomena could in the last analysis be reduced. The century over which we now look back, with its wonderful advance in the methods and technique of exact observation, has been a period of specialisation or decentralisation. Have we now reached a point where science can again become universal in its ultimate outlook ? Has a scientific world-picture become possible ?

Of course there can be no final picture at any one stage of culture. The canvas is as large as the universe, and the moving finger of humanity itself will fill it in from age to age. All the advances of knowledge, all the new insights gained from those advances, will from time to time be blended into that picture. To the deeper insight of every era of our human advance there has been some such world-picture, however vague and faulty. It has been continually changing with the changing knowledge and beliefs of man. Thus, there was the world of magic and animism, which was followed by that of the early Nature gods. There was the geocentric world, which still survives in the world of commonsense. There is the machine or mechanistic world-view dominant since the time of Galileo and Newton, and now, since the coming of Einstein, being replaced by the mathematician's conception of the universe as a symbolic structure of which no mechanical model is possible. All these world-views have in turn obtained currency according as some well-defined aspect of our advancing knowledge has from time to time been dominant. My object is to focus attention on the sort of world-picture which results from the advances of physical, biological, and mental science during the period covered roughly by the activities of our Association. Science arose from our ordinary experience and commonsense outlook. The world of commonsense is a world of matter, of material stuff, of real separate things and their properties which act on each other and cause changes in each other. To the various things observable by the senses were added the imperceptible things—space and time, invisible forces, life, and the soul. Even these were not enough, and the supernatural was added to the natural world. The original inventory was continually being enlarged, and thus a complex empirical world-view arose, full of latent contradictions, but with a solid basis of actual experience and facts behind it.

Speaking generally, we may say that this is substantially still the commonsense view of the world and the background of our common practical beliefs.

How has science dealt with this commonsense empirical world-view? The fundamental procedure of science has been to rely on sense observation and experiment, and to base theory on fact. Thus the vast body of exact science arose, and all entities were discarded which were either inconsistent with observed facts or unnecessary for their strict interpretation. The atomic view of matter was established. Ether was given a status in the physical order which is now again being questioned in the light of the conception of space-time. New entities like energy emerged; old entities like forces disappeared; the principle of the uniformity of Nature was established; the laws of motion, of conservation, and of electromagnetism were formulated; and on their basis a closed mechanistic order of Nature was constructed, forming a rigid deterministic scheme. Into this scheme it has been difficult, if not impossible, to fit entities like life and mind; and the scientific attitude has on the whole been to put them to a suspense account and await developments. As to the supernatural, science is or has been agnostic, if not frankly sceptical.

Such, in very general terms, was the scientific outlook of the nineteenth century, which has not yet completely passed away. It will be noticed that much of the fundamental outlook of commonsense has thus survived, though clarified and purified by a closer accord with facts. This scientific view retained unimpaired and indeed stressed with a new emphasis, the things of commonsense, matter, time, and space, as well as all material or physical entities which are capable of observation or experimental verification. Nineteenth-century science is, in fact, a system of purified, glorified commonsense. Its deterministic theory certainly gave a shock to the common man's instinctive belief in free will; in most other respects it conformed to the outlook of commonsense. It is true that its practical inventions have produced the most astounding changes in our material civilisation, but neither in its methods nor in its world-outlook was there anything really revolutionary.

Underneath this placid surface the seeds of the future were germinating. With the coming of the twentieth century fundamental changes began to set in. The new point of departure was reached when physical science ceased to confine its attention to the things that are observed. It dug down to a deeper level, and below the things that appear to the senses it found, or invented, at the base of the world, so-called scientific entities, not capable of direct observation, but which are necessary to account for the facts of observation. Thus, below molecules and atoms still more ultimate entities appeared; radiations, electrons, and protons emerged as elements which underlie and form our world of matter. Matter itself, the time-honoured mother of all, practically disappeared into electrical energy.

"The cloud-capp'd towers, the gorgeous palaces,
The solemn temples, the great globe itself,"

Yea, all the material forms of earth and sky and sea were dissolved and spirited away into the blue of energy. Outstanding among the men who brought about this transformation are two of my predecessors in this chair. Sir J. J. Thomson and Lord Rutherford. Like Prospero, like Shakespeare himself, they must be reckoned among the magicians.

Great as was this advance, it does not stand alone. Away in the last century, Clerk Maxwell, following up Faraday's theories and experiments, had formulated his celebrated equations of the electromagnetic field, which applied to light no less than to electromagnetism, and the exploration of this fruitful subject led Minkowski to the amazing discovery in 1908 that time and space were not separate things, but constituent elements in the deeper synthesis of space-time. Thus time is as much of the essence of things as space; it enters from the first into their existence as an integral element. Time is not something extra and superadded to things in their behaviour, but is integral and basic to their constitution. The stuff of the world is thus envisaged as events instead of material things.

This physical concept or insight of space-time is our first revolutionary innovation, our first complete break with the old world of commonsense. Already it has proved an instrument of amazing power in the newer physics. In the hands of an Einstein it has led, beyond Euclid and Newton, to the recasting of the law and the concept of gravitation, and to the new relativity conception of the basic structure of the world. The transformation of the concept of space, owing to the injection into it of time has destroyed the old passive homogeneous notion of space and has substituted a flexible, variable continuum, the curvatures and unevenness of which constitute to our senses what we call a material world. The new concept has made it possible to construe matter, mass and energy as but definite measurable conditions of curvature in the structure of space-time. Assuming that electromagnetism will eventually follow the fate of gravitation, we may say that space-time will then appear as the scientific concept for the only physical reality in the universe, and that matter and energy in all their forms will have disappeared as independent entities, and will have become mere configurations of this space-time. This will probably involve an amplified concept of space-time. Einstein has recently indicated that for further advance a modification in our space-time concept will become necessary, and that the additional element of direction will have to be incorporated into it. Whatever change may become necessary in our space-time concept, there can be no doubt about the immense possibilities it has opened up.

I pass on to an even more revolutionary recent advance of physics. The space-time world, however novel, however shattering to commonsense, is not in conflict with reason. Indeed, the space-time world is largely a discovery of the mathematical reason, and is an entirely rational world. It is a world where reason, as it were, dissolves the refractoriness of the old material substance and smoothes out into forms of space-time. Science, which began with empirical brute facts, seems to be heading for the reign of pure reason. But wait a bit; another fundamental discovery of our age has apparently taken us beyond the bounds of rationality, and is thus even more revolutionary than that of space-time. I refer to the quantum theory, Max Planck's discovery at the end of the nineteenth century, according to which energy is granular, consisting of discrete grains or quanta. The world in space-time is a continuum; the quantum action is a negation of continuity. Thus arises the contradiction, not only of commonsense, but apparently also of reason itself. The quantum appears to behave like a particle, but a particle out of space or time. As Sir Arthur Eddington graphically puts it; a quantum of light is large enough to fill the lens of a hundred-inch telescope, but it is also small enough to enter an atom. It may spread like a circular wave through the universe, but when it hits its mark this cosmic wave instantaneously contracts to a point where it strikes with its full and undivided force.

Space-time, therefore, does not seem to exist for the quantum, at least not in its lower multiples. Nay, more; the very hitting of its mark presents another strange puzzle, which seems to defy the principles of causation and of the uniformity of Nature, and to take us into the realm of chance and probability. The significant thing is that this strange quantum character of the universe is not the result of theory, but is an experimental fact well attested from several departments of physics. In spite of the strange Puck-like behaviour of the quantum, we should not lightly conclude, with some prominent physicists, that the universe has a skeleton in its cupboard in the shape of an irrational or chaotic factor. Our microscopic concepts may not fit this ultra-microscopic world of the quantum. Our best hopes for the future are founded on the working out of a new system of concepts and laws suited to this new world that has swum into the ken of science. The rapid development of wave mechanics in the last four years seems to have brought us within sight of this ideal, and we are beginning to discern a new kind of order in the microscopic elements of the world, very different from any type of law hitherto imagined in science, but nonetheless a rational order capable of mathematical formulation.

We may summarise these remarks by saying that the vastly improved technique of research has led to physical discoveries in recent years which have at last compl-

etely shattered the traditional commonsense view of the material world. A new space-time world has emerged which is essentially immaterial, and in which the old-time matter, and even the scientific mass, gravitation, and energy stand for no independent entities, but can best be construed as configurations of space-time; and the discovery of the quantic properties of this world points to still more radical transformations which loom on the horizon of science. The complete recasting of many of our categories of experience and thought may ultimately be involved.

From the brilliant discoveries of physical science we pass on to the advances in biological science which, although far less revolutionary, have been scarcely less important for our world-outlook. The most important biological discovery of the last century was the great fact of organic evolution; and for this fact the space-time concept has at last come to provide the necessary physical basis. It is unnecessary for my purpose to canvass the claims and discuss the views represented by the great names of Lamarck, Darwin, and Mendel, beyond saying that they represent a progressive advance in biological discovery, the end of which has by no means been reached yet. Whatever doubts and differences of opinion there may be about the methods, the mechanism, or the causes, there is no doubt about the reality of organic evolution, which is one of the most firmly established results in the whole range of science. Palaeontology, embryology, comparative anatomy, taxonomy and geographical distribution all combine to give the most convincing testimony that, throughout the history of this earth, life has advanced genetically from at most a few simple primitive forms to ever more numerous and highly specialised forms. Under the double influence of the internal genetic and the external environmental factors, life has subtly adapted itself to the everchanging situations on this planet. In the process of this evolution not only new structures and organs, but also new functions and powers have successively appeared, culminating in the master key of mind and in the crowning achievement of human personality. To have hammered the great truth of organic evolution into the consciousness of mankind is the undying achievement of Charles Darwin, by the side of which his discovery of natural selection as the method of evolution is of secondary importance.

The acceptance of the theory of evolution has brought about a far-reaching change in our outlook on the universe and our sense of values. The story of creation, so intimately associated with the groundwork of most religions, has thus come to be rewritten. The unity and interconnexions of life in all its manifold forms have been clearly recognised, and man himself has had to come down from his privileged position among the angels and take his proper place in the universe as part of the order of Nature. Thus Darwin completes the revolution begun by Copernicus.

Space-time finds its natural completion in organic evolution. For in organic evolution the time aspect of the world finds its most authentic expression. The world truly becomes a process, where nothing ever remains the same or is a duplicate of anything else, but a growing, gathering, creative stream of unique events rolls forever forward.

While we recognise this intimate connexion between the conceptions of space-time and organic evolution, we should be careful not to identify the time of evolution with that of space-time. There is a very real difference between them. Biological time has direction, passes from the past to the future, and is therefore historical. It corresponds to the 'before' and 'after' of our conscious experience. Physical time as an aspect of space-time is neutral as regards direction. It is space-like, and may be *plus* or *minus*, but does not distinguish between past or future. It may move in either direction, backwards or forwards, while biological time, like the time of experience, knows only a forward flow. Hence cosmic evolution, as we see it in astronomy and physics, is mostly in an opposite direction to that of organic evolution. While biological time on the whole shows a forward movement towards ever higher organisation and rising qualities throughout the geological ages, the process of the physical world is mostly in the opposite direction* -towards disorganisation, disintegration of more complex structures, and dissipation of energy.

The second law of the thermodynamics thus marks the direction of physical time. While the smaller world of life seems on the whole to be on the up-grade, the larger physical universe is on the down-grade. One may say that in the universe we witness a majority movement and a minority movement upward. The energy which is being dissipated by the decay of physical structure is being partly taken up and organised into life structures at any rate on this planet. Life and mind thus appear as products of the cosmic decline, and arise like the phoenix from the ashes of a universe radiating itself away. In them Nature seems to have discovered a secret which enables her to irradiate with imperishable glory the decay to which she seems physically doomed.

Another striking point arises here. Organic evolution describes the specific process of what we call life, perhaps the most mysterious phenomenon of this mysterious universe. When we ask what is the nature of life we are curiously reminded of the behaviour of the quantum referred to. I do not for a moment wish to say that the quantum is the physical basis of life, but I do say that in the

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* No doubt there are exceptions to this broad generalisation. In astronomy stars and solar systems and galaxies are probably still being formed, while in physics syntheses of elements may possibly still be going on. In the same way we find in organic evolution minor phases of regression, degeneration, and parasitism.

quantum the physical world offers an analogy to life which is at least suggestive. The quantum follows the all-or-nothing law and behaves as an indivisible whole: so does life. A part of a quantum is not something less than a quantum; it is nothing or sheer nonentity; the same holds true of life.

The quantum is perharps most easily symbolised as a wave or combination of waves, which can only exist as a complete periodicity, and the very concept of which negatives its existence as partial or truncated. In other words, it is a specific configuration and can only exist as such: the same holds true of life. The quantum does not fall completely within the deterministic causal scheme: the same seems true of life.

Significant also is the fact that quantum phenomena underlie secondary qualities such as colour and the like, which the older science in its mechanistic scheme ignored but which are specially associated with life and consciousness. Life is not an entity, physical or other. It is a type of organisation; it is a specific principle of central or self-organisation. If that organisation is interfered with we are left, not with bits of life, but with death. The nature of living things is determined, not by the nature of their parts, but by the nature or principle of their organisation. In short, the quantum and life seem to have this in common, that they both behave as wholes.

I have before now endeavoured to explore the concept of life in the light of the more general concept of the whole. A whole is not a sum of parts, or constituted by its parts. Its nature lies in its constitution more than in its parts. The part in the whole is no longer the same as the part in isolation. The interesting point is that while this concept of the whole applies to life, it is according to the recent physics no less applicable to the ultimate physical units. Thus the electron within an atom is no longer a distinct electron. There may be separate electrons, but when they cease to be separate they also cease to be. The eight electrons which circulate in an oxygen atom are merged in a whole in such a way that they have lost their separate identity; and this loss of individuality has to be taken into account in calculations as to the physical behaviour of the atom. The physicist, in fact, finds himself unable to look upon the entity which is one-eighth of eight electrons as the same thing as a single electron. At the very foundation, therefore of physics, the principle or category of the whole applies no less than in the advanced structure of life, although not in the same degree. In the ultimate analysis of the world, both at the physical and the biological level, the part or unit element somehow becomes shadowy and incoherent, and the very basis of mechanism is undermined. It would almost seem as if the world in its very essence is holistic,

and as if the notion of individual parts is a practical makeshift without final validity in the nature of things.

The general trend of the recent advances in physics has thus been towards the recognition of the fundamental organic character of the material world. Physics and biology are beginning to look not so utterly unlike each other. Hitherto the great gulf in Nature has lain between the material and the vital, between inorganic matter and life. This gulf is now in process of being bridged. The new physics, in dissolving the material world of commonsense and discovering the finer structure of Physical Nature, has at the same time disclosed certain fundamental features which it has in common with the organic world. Stuff-like entities have disappeared and have been replaced by space-time configurations, the very nature of which depends on their principle of organisation. This principle, which I have ventured to call holism, appears to be at bottom identical with that which pervades the organic structures of the world of life. The quantum and space-time have brought physics closer to biology. As I have pointed out the quantum anticipates some of the fundamental characters of life, while space-time forms the physical basis for organic evolution. Physics and biology are thus recognised as respectively simpler and more advanced forms of the same fundamental pattern in world structure.

The older mechanistic conception of Nature, the picture of Nature as consisting of fixed material particles, mechanically interacting with each other already rudely shaken by the relativity theory—is now being modified by the quantum physics. The attack on mechanism, thus coming from physical science itself, is therefore all the more deadly. Even in physics, organisation is becoming more important than the somewhat nebulous entities which enter into matter. Interaction is more and more recognised to be not so much mechanical as organic or holistic, the whole in some respects dominating not only the functioning but also the very existence of the entities forming it. The emergence of this organic view of Nature from the domain of physics itself is thus a matter of first-rate importance, and must have very far-reaching repercussions for our eventual world-view.

The nature of the organic whole is, however, much more clearly recognised in its proper sphere of biology, and especially in the rapidly advancing science of physiology. Here, too, the correct view has been much obscured by the invasion of mechanistic ideas from the physics of the nineteenth century. A crude materialism all but swamped biology for more than a generation. At the Belfast meeting of the British Association in 1874, a famous predecessor of mine gave unrestrained expression to this materialistic creed. All that is passing, if not already past. It must be admitted that up to a point mechanism has been useful as a first approxi-

mation and fruitful as a convention for research purposes. But if even in physics it has lost its savour, *a fortiori* has it become out of place in biology. The partial truth of mechanism is always subtended by the deeper truth of organicity or holism. So far from biology being forced into a physical mould, the position will in future be reversed. Physics will look to biology and even to psychology for hints, clues, and suggestions. In biology and psychology it will see principles at work in their full maturity which can only be faintly and fitfully recognised in physics. In this way the exchanges of physics, biology, and psychology will become fruitful for the science of the future, and lay the basis for a new scientific monism.

A living individual is a physiological whole, in which the parts or organs are but differentiations of this whole for purposes of greater efficiency, and remain in organic continuity throughout. They are parts of the individual, and not independent or self-contained units which *compose* the individual. It is only this conception of the individual as a dynamic organic whole which will make intelligible the extraordinary unity which characterises the multiplicity of functions in an organism, the mobile, ever-changing balance and interdependence of the numerous regulatory processes in it, as well as the operation of all the mechanisms by which organic evolution is brought about. This conception applies not only to individuals, but also to organic societies, such as a beehive or an ant's nest, and even to social organisations on the human level.

As the concept of space-time destroys the purely spatial character of things, so the concept of the organic whole must also be extended beyond the spatial limits of the organism so as to include its interaction with its environment. The stimuli and responses which render them mutually interdependent constitute them one whole which thus transcends purely spatial aspects. It is this overflow of organic wholes beyond their apparent spatial limits which binds all Nature together and prevents it from being a mere assemblage of separate interacting units.

It is time, however, that we pass on to the world of mind. From matter, as now transformed by space-time and the quantum we pass step by step through organic nature to conscious mind. Gone is the time when Descartes could divide the world into only two substances: extended substance or matter, and thinking substance or mind. There is a whole world of gradations between these two limits. On Descartes' false dichotomy the separate provinces of modern science and philosophy were demarcated. But it is as dead as the epicycles of Ptolemy, and ultimately the Cartesian frontiers between physics and philosophy must largely disappear, and philosophy once more become metaphysic in the original sense. In the meantime, under its harmful influence, the paths of matter and mind, of science

and philosophy, were made to diverge farther and farther, so that only the revolution now taking place in thought could bring them together again. I believe, however, their reunion is coming fast. We have seen matter and life indefinitely approaching each other in the ultimate constituents of the world. We have seen that matter is fundamentally a configuration or organisation of space-time; and we have seen that life is a principle of organisation whereby the space-time patterns are arranged into organic unities. The next step is to show that mind is an even more potent embodiment of the organising whole-making principle, and that this embodiment has found expression in a rising series, which begins practically on the lowest levels of life, and rises ultimately to the conscious mind which alone Descartes had in view in his classification. I have no time to follow up the matter here beyond making a few remarks.

Mind is admittedly an active, conative, organising principle. It is for ever busy constructing new patterns of things, thoughts, or principles out of the material of its experience. Mind, even more than life, is a principle of whole-making. It differentiates, discriminates and selects from its vague experience, and fashions and correlates the resulting features into more or less stable, enduring wholes. Beginning as mere blind tropisms, reflexes, and conditioned reflexes, mind in organic Nature has advanced step by step in its creative march until in man it has become Nature's supreme organ of understanding, endeavour, and control -not merely a subjective human organ, but Nature's own power of self-illumination and self-mastery: "The eye with which the universe beholds itself and knows itself divine."

The free creativeness of mind is possible because, as we have seen, the world ultimately consists, not of material stuff, but of patterns, of organisation, the evolution of which involves no absolute creation of an alien world of material from nothing. The purely structural character of reality thus helps to render possible and intelligible the free creativeness of life and mind, and accounts for the unlimited wealth of fresh patterns which mind freely creates on the basis of the existing physical patterns.

The highest reach of this creative process is seen in the realm of values which is the product of the human mind. Great as is the physical universe which confronts us as a given fact, no less great is our reading and evaluation of it in the world of values, as seen in language, literature, culture, civilization, society and the State, law, architecture, art, science, morals, and religion. Without this revelation of inner meaning and significance the external physical universe would be but an immense empty shell or crumpled surface. The brute fact here receives its meaning, and a new world arises which gives to Nature whatever significance it

has. As against the physical configurations of Nature we see here the ideal patterns or wholes freely created by the human spirits as a home and an environment for itself.

Among the human values thus created science ranks with art and religion. In its selfless pursuit of truth, in its vision of order and beauty, it partakes of the quality of both. More and more it is beginning to make a profound aesthetic and religious appeal to thinking people. Indeed, it may fairly be said that science is perhaps the clearest revelation of God to our age. Science is at last coming into its own as one of the supreme goods of the human race.

While religion, art, and science are still separate values, they may not always remain such. Indeed, one of the greatest tasks before the human race will be to link up science with ethical values, and thus to remove grave dangers threatening our future. A serious lag has already developed between our rapid scientific advance and our stationary ethical development, a lag which has already found expression in the greatest tragedy of history. Science must itself help to close this dangerous gap in our advance which threatens the disruption of our civilisation and the decay of our species. Its final and perhaps most difficult task may be found just here. Science may be destined to become the most effective drive towards ethical values, and in that way to render its most priceless human service. In saying this I am going beyond the scope of science as at present understood but the conception of science itself is bound to be affected by its eventual integration with the other great values.

I have now finished my rapid and necessarily superficial survey of the more prominent recent tendencies in science, and I proceed to summarise the results and draw my conclusions, in so far as they bear on our world-picture.

In the first place we have seen that in the ultimate physical analysis, science reaches a microscopic world of scientific entities, very different in character and behaviour from the macroscopic world of matter, space, and time. The world of atoms, electrons, protons, radiations and quanta does not seem to be in space-time or to conform to natural law in the ordinary sense. The behaviour of these entities cannot be understood without the most abstruse mathematics or, apparently, without resort to epistemological considerations. We seem to have passed beyond the definitely physical world into a twilight where prophysics and metaphysics meet, where space-time does not exist, and where strictly causal law in the old sense does not apply. From this uncertain nebulous underworld there seems to crystallise out or literally to materialise, the macroscopic world which is the proper sphere of sensuous observation and of natural laws. The pre-material entities or units condense and cohere into constellations, which increase in size and structure until they

reach the macroscopic stage of observation. As the macroscopic entities emerge, their space-time field and appropriate natural laws (mostly of a statistical character) emerge *pari passu*. We seem to pass from one level to another in the evolution of the universe, with different units, different behaviours, and calling for different concepts and laws. Similarly, we rise to new levels as later on we pass from the physical to the biological level, and again from the latter to the level of conscious mind. But and this is the significant fact --all these levels are genetically related and form an evolutionary series; and underlying the differences of the successive levels, there remains a fundamental unity of plant or organisation which binds them together as members of a genetic series as a growing, evolving, creative universe.

In the second place, let us see how commonsense deals with this macroscopic world. On this stage common sense recognises three levels of matter, life, and mind as together composing the world. But it places them so far apart, and makes them so inherently different from each other, that relations between them appear unintelligible, if not impossible. The commonsense notions of matter, life, and mind make any relations between them, as well as the world which they form, an insoluble puzzle. The older science therefore attempted to reduce life substantially to terms of matter, and to put a question mark behind mind ; and the result was a predominantly materialistic view of the world. The space-time relativity concept of the world has overcome the difficulty by destroying the old concept of matter, and reducing it from a self-subsistent entity to a configuration of space-time—in other words, to a special organisation of the basic world-structure. If matter is essentially immaterial structure or organisation, it cannot fundamentally be so different from organism or life, which is best envisaged as a principle of organisation ; or from mind, which is an active organiser.

Matter, life, and mind thus translate roughly into organisation, organism, organiser. The all-or-none law of the quantum, which also applies to life and mind, is another indication that matter, life, and mind may be but different stages or levels of the same activity in the world which I have associated with the pervading feature of whole-making. Materialism has thus gone by the board, and the unintelligible trinity or common sense (matter, life, mind) has been reinterpreted and transformed and put on the way to a new monism.

In the third place, the iron determination of the older science, so contrary to direct human experience, so destructive of the free activity of life and mind, as well as subversive of the moral responsibility of the individual, has also been materially recast. It was due to the Newtonian causal scheme which, as I have indicated, has been profoundly shaken by recent developments. Relativity reduces substance to

configuration or patterns, while quantum physics gives definite indications of indeterminism in Nature. In any case, life through the ages shows clearly a creative advance to ever more complex organisation, and ever higher qualities, while mind is responsible for the creation of a whole realm of values. We are thus justified in stressing, along with natural necessity, an increasing measure of freedom and creativeness in the world, sufficient at least to account for organic evolution and for the appearance of moral law and endeavour.

This liberation of life and spirit from the iron rule of necessity is one of the greatest gains from the recent scientific advances. Nature is not a closed physical circle, but has left the door open to the emergence of life and mind and the development of human personality. It has, in its open flexible physical patterns, laid the foundation and established the environment for the coming of life and mind. The view, to which Huxley once gave such eloquent and poignant expression, of a dualism implanted in the heart of Nature, of a deadly struggle between cosmic law and moral law, is no longer justified by the subsequent advances of science.

In the fourth place, however, another dualism of a wider reach has appeared, which makes the universe itself appear to be a house divided against itself. For while the stream of physical tendency throughout the universe is on the whole downward, toward disintegration and dissipation, the organic movement, on this planet at least, is upward, and life structures are on the whole becoming more complex throughout the course of organic evolution. From the viewpoint of physics, life and mind are thus singular and exceptional phenomena, not in line with the movement of the universe as a whole. Recent astronomical theory has come to strengthen this view of life as an exceptional feature off the main track of the universe. For the origin of our planetary system is attributed to an unusual accident and planets such as ours with a favourable environment for life are taken to be rare in the universe. Perhaps we may even say that at the present epoch there is no other globe where life is at the level manifested on the earth. Our origin is thus accidental, our position is exceptional, and our fate is sealed, with the inevitable running down of the solar system. Life and mind, instead of being the natural flowering of the universe, are thus reduced to a very casual and inferior status in the cosmic order. A new meaning and a far deeper poignancy are given to Shakespeare's immortal lines :

> "We are such stuff
> As dreams are made of ; and our little life
> Is rounded with a sleep."

According to astronomy, life is indeed a lonely and pathetic thing in this physical universe - a transient and embarrassed phantom in an alien, if not hostile, universe.

Such are some of the depressing speculations of recent astronomical theory. But in some respects they have already been discounted in the foregoing. For even if life be merely a terrestrial phenomenon, it is by no means in an alien environment if, as we have reason to think, this is an essentially organic universe. In its organic aspects the universe is on the way to life and mind, even if the goal has been actually reached at only one insignificant point in the universe. The potencies of the universe are fundamentally of the same order as its actualities. The universe might say, in the words of Rabbi Ben Ezra :—

> " All I could never be
> All man ignored in me,
> This I was worth to God."

Then again, the very possibility of perception of knowledge and science, depends, on an intimate relation between mind and the physical universe. Only thus can the concepts of mind come to be a measure for the facts of the universe, and the laws of Nature come to be revealed and interpreted by Nature's own organ of the human mind. Besides science we have other forms of this inner relation between the mind and the universe, such as poetry, music, art, and religion. The human spirit is not a pathetic wandering phantom of the universe, but is at home, and meets with spiritual hospitality and response everywhere. Our deepest thoughts and emotions and endeavours are but responses to stimuli which come to us, not from an alien, but from an essentially friendly and kindred universe. So far from the cosmic status of life and mind being degraded by the newer astronomy and physics, I would suggest an alternative interpretation of the facts, more in accord with the trend of evolutionary science. We have seen a macroscopic universe born or revealed to consciousness out of a prior microscopic order of a very different character. Are we not, in the emergence of life and mind, witnessing the birth or revelation of a new world out of the macroscopic physical universe ? I suggest that at the present cosmic epoch we are the spectators of what is perhaps the grandest event in the immeasurable history of our universe, and that we must interpret the present phase of the universe as a mother and child universe, still joined together by a placenta which science, in its divorce from the other great values, has hitherto failed to unravel.

Piecing together these clues and conclusions, we arrive at a world-picture fuller of mystery than ever. In a way it is closer to common sense and kinder to human nature than was the science of the nineteenth century. Materialism has practically disappeared, and the despotic rule of necessity has been greatly relaxed. In ever-varying degree the universe is organic and holistic through and through. Not only organic concepts, but also, and even more so, psychological view points are becoming necessary to elucidate the facts of science ; and while the purely

human concepts, such as emotion and value, purpose and will, do not apply in the natural sciences, they retain their unimpaired force in the human sciences. The ancient spiritual goods and heirlooms of our race need not be ruthlessly scrapped. The great values and ideals retain their unfading glory and derive new interest and force from a cosmic setting.

In other respects it is a strange new universe, impalpable, immaterial, consisting not of material or stuff, but of organisation, of patterns or wholes which are unceasingly being woven to more complex or to simpler designs. In the large it appears to be a decaying, simplifying universe which attained to its perfection of organisation in the far-distant past and is now regressing to simpler forms—perhaps for good, perhaps only to restart another cycle of organisation. But inside this cosmic process of decline we notice a smaller but far more significant movement, a streaming, protoplasmic tendency; an embryonic infant world emerging, throbbing with passionate life, and striving towards rational and spiritual self-realisation. We see the mysterious creative rise of the higher out of the lower, the more from the less, the picture within its framework, the spiritual kernel inside the phenomenal integuments of the universe. Instead of the animistic, or the mechanistic, or the mathematical universe, we see the genetic, organic, holistic universe, in which the decline of the earlier physical patterns provides the opportunity for the emergence of the more advanced vital and rational patterns.

In this holistic universe man is in very truth the offspring of the stars. The world consists not only of electorns and radiations, but also of souls and aspirations. Beauty and holiness are as much aspects of Nature as energy and entropy. Thus "in eternal lines to time it grows". An adequate world-view would find them all in their proper context in the framework of the whole; and evolution is perhaps the only way of approach to the framing of a consistent world-picture which would do justice to the immensity, the profundity, and the unutterable mystery of the universe.

Such in vague outline is the world-picture to which science seems to me to be pointing. We may not all agree with my rendering of it, which indeed does not claim to be more than a mere sketch. Even if it were generally accepted, we have still to bear in mind that the world-picture of to-morrow will in all probability be very different from any which could be sketched to-day.

SCIENTIFIC SYSTEM OF RATIONING FARM CATTLE AS WELL AS SUGGESTIONS TO EFFECT THEIR IMPROVEMENT.

BY

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"No human capacity ever yet saw the whole of a thing, but we may see more and more of it, the longer we look."

—RUSKIN.

This is in continuation of the writer's article* on "Feeding of Farm Cattle" in Poona Agricultural College Magazine, Vol. XXII. No. 2. September 1930, wherein it has been pointed out that there are. in the main. four different ways by which economies in the cost of feeding can be effected, *viz.*—

(1) Feeding the animal on well balanced ration.

(2) Purchasing the cheapest suitable food.

(3) Reducing the cost of production of home-grown food.

(4) Evolving strains of animals of better yield or production by selection and breeding.

FEEDING THE ANIMAL ON A WELL BALANCED RATION.

This has been discussed at length in the writer's article mentioned above. But since the date of writing that article, the writer has been able to compute still simpler formulæ, which are tabulated as under, for the benefit of live stock farmers.

*Reprinted in this Journal, Vol. I, Part III, May, 1931.

Amount in lbs. for→ / Nature of requirements ↓		Animal on maintenance ration	Cow yielding milk	Cow-in-Calf yielding milk	Dry Cow just before calving	Working bullock			Fattening animal after it has ceased producing in other directions
						on light work	on medium work	on heavy work	
Starch equivalents		$\frac{Lw}{250} + 2 = x$	$x + \frac{m \times f}{16}$	$x + \frac{m \times f}{16} + 1$	$x + 1$	$x + \frac{\frac{1}{2}hr \times Lw}{1000}$	$x + \frac{\frac{3}{4}hr \times Lw}{1000}$	$x + \frac{hr \times Lw}{1000}$	$x + 2{\cdot}5$ L.W.I.
Digestible proteins		$\cdot 0006 \times Lw = y$	$y + \frac{m \times f}{80}$	$y + \frac{m \times f}{80} + \cdot 3$	$y + \cdot 3$	$y + \frac{\frac{1}{2}hr \times Lw}{10000}$	$y + \frac{\frac{3}{4}hr \times Lw}{10000}$	$y + \frac{hr \times Lw}{10000}$	$y + \cdot 25$ L.W.I.
Dry matter	Minimum coarse fodder	2x	$2x \times \frac{m \times f}{16}$	$2x \times \frac{m \times f}{16}$	2x	2x	2x	2x	2x
	Maximum amount in ration	3·6x	$3{\cdot}6x \times \frac{m \times f}{16}$	$3{\cdot}6x \times \frac{m \times f}{16}$	3·6x	3·6x	3·6x	3·6x	3·6x

Explanation of abbreviations :—
f = butter fat percentage of milk; hr = number of hours wrought; Lw = live weight; L.W.I. = live weight increase; m = milk yield in lbs.; x = starch equivalent for maintenance; y = digestible protein for maintenance

The above table shows the amount of daily ration to be given to each of the animals of different weights and under different state and degree of production except to those that are not yet weaned. Its use renders the construction of a ration as simple as possible, eliminating at the same time the necessity of committing to memory a great many figures otherwise, and give figures of starch equivalents, digestible proteins and dry matter which correspond fairly approximately to those required by the most up-to-date and scientific standards.

In order, however, that we should be able to follow this method, it is necessary to know the starch equivalents and digestible proteins of the common foodstuffs used in India; but unfortunately these have not been determined for Indian foodstuffs under Indian conditions through actual feeding experiments to any appreciable extent if at all. In the absence of these data, the next best thing that we can do would be to compute the figures from chemical analysis of foodstuffs. In doing so, let it be assured we shall not be erring to any appreciable extent. Small deviations that may occur from the normal requirements should not matter at all, because no method is known or likely to be evolved that will go to eliminate the possibility of occurrence of deviation. But here too we come across with difficulties, because computation is not possible unless we know the digestibility of feeding stuffs. Coefficients of digestion are, however, not worked out in India, at least in a way that we might make use of them in computing figures for starch equivalents. After considering every thing, therefore, the most feasible course that lies before us at present is to adopt for common feeding stuffs used in this country either Kellner's figures of *starch equivalents* or Armby's figures of *net energy therms*. Both these figures are equally good but in order to be able to derive benefit of the writer's computed formulæ as given in the above table, the writer suggests the use of Kellner's standard of starch equivalents. No doubt there would be certain foodstuffs for which figures of starch equivalents are not available, but if, however, in place of starch equivalents figures for net energy therms can be had, it will not make any difference in the way of construction of a ration by Kellner's standard; because net energy therms can be turned into starch equivalents by multiplying the former by 1·07. The general composition of feeds of foreign countries where the system based on starch equivalents or net energy therms is widely adopted, is somewhat different from that of the feeds of this country, as a number of those used in this country are not used in those foreign countries. *Jowar kadbi* which forms usually a constant part of animal ration in the Deccan may be cited as an example. But for such foodstuffs we shall not be erring to any appreciable extent if we assign such figures for starch equivalents as are possessed by kindred foodstuffs.

There are two very obvious advantages of following the system of rationing by starch equivalents or net energy therms. In the first place, the standard could be expressed in a single figure, instead of three figures, one for protein, one for fat. and one for carbohydrate. Secondly the figure is also a net figure directly related to the result it may be expected to produce. No doubt, a standard based on total nutrients could also be expressed in a single figure but it represents the total gross digestible energy, so that while it may be more accurate while calculating the maintenance part of a ration, it fails to show in a definite manner any correlation with the amount of production.

Ratio of starch equivalents to digestible proteins :—For an ordinary animal of a herd of dairy cattle ratio of S.E. to D.P. is as follows :—

1. For an animal on maintenance ration :

Live weight	Ratio
800 lbs.	9·4
900 ,,	9·7
1000 ,,	10·0
1100 ,,	10·4
1200 ,,	10·9

2. Ration for milk production has a ratio of 5.

3. Ration for maintenance *plus* production.

If we take an ordinary animal of a herd of dairy cattle, say weighing 1000 lbs. Lw, the ratio would be under varying quantities of milk of 4 per cent. butter fat, as under :—

Milk yield in lbs.	Ratio
8	8·0
10	7·7
12	7·5
14	7·3
16	7·1
18	7·0
20	6·9
...	...
30	5·9

From the above it is obvious that (*a*) unless variation in the live weight of animals is rather great—say above 200 lbs.—there is practically no appreciable difference between the ratios of S.E. to D.P. of a maintenance ration. (*b*) The ratio for ration for milk production is a constant figure, *viz.*, 5, which goes to reduce still further the difference between such ratios, on account of differences in live weights and that (*c*) provided the difference in milk yield is indeed very great, the ratio remains more or less constant.

Taking the above facts into consideration and making use of the formulæ given in the above table, we can proceed to adjust a ration for any animal in the following manner :—

(1) Leaving out of count young suckling animals, divide the rest of the dairy animals into two groups—(*a*) a group of non-producers, which are still but young heifers and (*b*) a group of milk yielders.

(2) Determine the live weights of individual animals and further divide them into sub-groups on the basis of live weights so that the maximum difference that may be allowed between the two extreme individuals of a group does not exceed 200 lbs.

(3) Determine the amount of individual production and still further sub-group them on the basis of milk yield, so that the maximum difference that may be allowed between the two extreme individuals of a sub-group should not exceed 10 lbs. On an usual sort of a dairy concern where the individuals belong to more or less the same breed, sub-grouping will not be necessary except the preliminary grouping into two lots, *viz.*, one of non-producers and another of producers.

(4) Apportion per animal dry fodder and succulents that may be available on the farm. As a rule an animal in the group of high producers should have roughages apportioned to it in less quantities than an animal in the group of low producers; while animals in the same group should get these in equal proportions. Starch equivalents of a maintenance part of a ration should be made up as far as possible of roughages, because the standard for maintenance has been based by feeding roughages, which, besides providing the net matabolisable energy as expressed by their starch equivalents, also produce a certain amount of heat which the animal can utilise for warming the body, food and water, which would otherwise have to be warmed at the expense of starch equivalents if no extra heat is generated. If concentrates are used as a source of energy for maintenance, starch equivalents are, in fact, required to be given in larger quantities than are generally advocated by the standard, because these do not generate much heat while undergoing the process of mastication and digestion. Hence concentrates as a ration for maintenance are less economical to use than roughages. However,

economy in the ration of each individual animal does not necessarily mean that it will also effect economy on the whole. The following procedure in apportioning dry fodder will make it very convenient to adjust the ration on the whole according to the standard.

(*a*) Find out the S. E. for maintenance of an animal whose live weight is least in a group and multiply it by $\frac{3\cdot5\times100}{85}$. This will give the maximum amount of dry fodder for this animal, and this will be well under maximum requirement of dry fodder for the rest of the animals in the group.

(*b*) Find out also the S. E. for maintenance of an animal whose live weight is highest in the same group and multiply it by $\frac{2\times100}{85}$. This will give the minimum amount of dry fodder for this animal and this will be well above the minimum requirement of dry fodder for the rest of the animals in the group.

On a farm where the object of keeping cattle is the utilisation of straw and other surplus farm products, live stock enterprise being subsidiary industry, apportionment of dry fodder should be nearer this maximum. But where the live stock enterprise constitutes the main industry, apportionment should be nearer the minimum so that the live stock carrying capacity of the farm is increased to its maximum. When the apportionment of dry fodder is within these two limits, there will be no difficulty in adjusting ration for total individual production in respect to total quantity of dry matter, as the latter will automatically adjust itself so as to remain within these two limits.

(5) Find out the total amount of S. E. and D. P. that will be required for an animal of the group whose live weight is the least. Also find out the number of lbs. of S. E. and D. P. contained in the apportioned roughages and succulents. Deduct the latter figures from the former. This will give you the amount of deficit S. E. and deficit D. P. Find out the ratio of deficit S. E. to deficit D. P.

(6) Make up the deficit by addition of concentrates. Addition of any concentrate whose ratio of S. E. to D. P. corresponds to that in the deficit will exactly balance D. P. if sufficient quantity is given to make up the deficit of S. E. But a single foodstuff of this ratio is not always easy to find, and even if it is available, may not necessarily be the cheapest or most suitable. Besides, it is inadvisable to use only one kind of concentrate food as its proteins may not contain all the requisite types of amino compounds. We should aim at giving at least two kinds of concentrated foodstuffs. The proportion in each of these foodstuffs should be such that the combined ratio of their S. E. to D. P. should correspond to that in the deficit. Combination for this purpose is only possible when one of the foodstuffs has narrower and the other wider ratio when compared to the ratio

in the deficit. Hence select a cheapest and most suitable foodstuff amongst those foodstuffs whose ratios of S. E. to D. P. are narrower and another cheapest and most suitable among those whose ratios are wider than the similar ratio in the deficit. The former may be selected from oil cakes and the latter from *chunis* or grain bye-products. Suppose A and B are two such foodstuffs, x is the ratio, of S. E. to D. P., y. the number of parts A should be taken for every part of B to obtain x ratio, S. E. the number of lbs. of starch equivalents per 100 lbs. of a foodstuff and D. P., the number of lbs. of digestible proteins per 100 lbs. of a foodstuff, then the value of y which is an unknown quantity can be determined by the following formula

$$y=\frac{x\times \text{D. P. of B}-\text{S. E. of B.}}{\text{S. E. of A}-x\times \text{D. P. of A.}}$$

After knowing the value of y you will then be in a position to determine the S. E. and D. P. per 100 lbs. of the mixture thus :

S. E. per 100 lbs. of the mixture

$$=\frac{y\times \text{S. E. per 100 lbs. of A} + \text{S. E. per 100 lbs. of B}}{y+1}$$

D. P. per 100 lbs. of the mixture

$$=\frac{y\times \text{D. P. per 100 lbs. of A} + \text{D. P. per 100 lbs. of B}}{y+1}$$

It is, however, even much better, provided it is not going to affect the economy, to give as many more foodstuffs as possible instead of only two. Under these circumstances divide the foodstuffs into two groups one group of narrower ratio and the other of wider ratio than the ratio of the deficit. Combine the foodstuffs in each group in whatever proportion you deem most suitable and find out the S. E. and D. P. per 100 lbs. of the mixture of each group. These two mixtures may then be treated as two different foodstuffs so that the proportion in which they should be combined to give a ratio of S. E. to D. P. corresponding to similar ratio in the deficit, as well as lbs. S. Es. and D. Ps. per 100 lbs. of the final mixture can be determined precisely in the same way as is done in the case when the proportion of only two foodstuffs is adjusted.

Example.—The ratio of deficit S. E. to deficit D. P. is 8. There are four concentrated foodstuffs selected—two (A & B) with narrower ratio and the other two (C & D) with wider ratio than 8. the ratio of the deficit. The S. E. and D. P.

per 100 lbs. and the ratios of S. E. to D. P. of these foodstuffs, as well as the proportion in which these are combined are as under :—

Group	Foodstuff	S. E. per 100 lbs.	D. P. per 100 lbs.	Ratio of S. E. to D. P.	Proportion in parts in which they are mixed
With ratio narrower than 8.	A	40	10	4	1
	B	60	10	6	4
With ratio wider than 8	C	54	6	9	2
	D	36	3	12	1

Find out the proportion in which they should be combined finally so that the ratio of their S. E. to D. P. is 8. Also find out the number of lbs. of S. E. and D. P. per 100 lbs. of the final combination.

Solution :—

S. E. per 100 lbs. of the mixture of A and B

=S. E. of A × parts + S. E. of B × parts ÷ total number of parts

= 40 × 1 + 60 × 4 ÷ 5

=*56*.

D. P. per 100 lbs. of the same

=D. P. of A × parts + D. P. of B × parts ÷ total number of parts

= 10 × 1 + 10 × 4 ÷ 5

=*10*.

S. E. per 100 lbs. of the mixture of C and D

=S. E. of C × parts + S. E. of D × parts ÷ total number of parts

= 54 × 2 + 36 × 1 ÷ 3

=*48*.

D. P. per 100 lbs. of the same

=D. P. of C × parts + D. P. of D × parts ÷ total number of parts

=6 × 2 + 3 × 1 ÷ 3

=*5*.

Now if *y* parts of C D mixture are combined with one part of A B mixture, the value of *y* would be

$$y=\frac{8 \times \text{D. P. of CD} - \text{S. E. of CD}}{\text{S. E. of AB} - 8 \times \text{D. P. of AB}} = 3$$

Therefore final proportion in which the foodstuffs should be fed would be as under :—

Food-stuff	Original proportions in parts	Parts of each group	If 1 lb. of each group is taken the following will be the proportion of each food	Multiply by	Final proportion		
A	1	5	$\frac{1}{5}$	1	$\frac{1}{5}$	OR	1
B	4		$\frac{4}{5}$		$\frac{4}{5}$		4
C	2	3	$\frac{2}{3}$	3	2		10
D	1		$\frac{1}{3}$		1		5

From these data we can find out the S. E. and D. P. per 100 lbs. of the final combination as under :—

S.E. of $A \times 1$+S.E. of $B \times 4$+S.E. of $C \times 10$+S.E. of $D \times 5 \div 20 = 50 =$ S. E. per 100 lbs.

D.P. of $A \times 1$+D.P. of $B \times 4$+D.P. of $C \times 10$+D.P. of $D \times 5 \div 20 = 6 \cdot 25 =$ D.P. per 100 lbs.

With this mixture in hand we can now conveniently proceed to feed any animal in the group on the basis of deficit S. E. alone.

Thus :

$$\frac{\text{Total requirement of S.Es.} - \text{S.Es. already apportioned equally} \times 100}{\text{S.E. per 100 lbs. of final concentrate mixture.}}$$

=lbs. of concentrate mixture.

The D. P. will automatically adjust itself.

Concentrate mixture for other class of farm cattle :—

Cows-in-calf, yielding milk if not in large numbers, may conveniently be placed in a suitable group only on the basis of live weight and milk yield without taking into consideration the fact that they have to nourish fœtus in addition for, on the whole ratio of S. E. to D. P. in their ration works out only slightly under than similar cows but bearing no fœtus. If, however, their number happens to be considerable and the protein-rich foods are much dearer than protein-poor foods, it will then be economical to prepare a separate concentrate mixture for making up the deficit.

Likewise, dry cows-in-calf may conveniently be accommodated in a suitable group of non-producers.

Working bullocks would require almost the same ratio as they do for their maintenance. If adequate amount of S. E. is supplied as a source of energy for work there would be no necessity to add any protein for the production of work except a small additional amount for making extra digestive juices and to increase the palatability of the ration. This can be done by keeping up in total ration the same ratio of S. E. to D. P. as is necessary in maintenance part of the ration. Hence working bullocks may conveniently be accommodated in a suitable group of non-producers in respect to their receiving a concentrate ration, without taking into consideration the fact that they have to perform work in addition.

Since the object, as a rule, of fattening of an animal in India is to give tone to its external appearance and increase the palatability and appearance of its flesh, with a view to enhance its sale price after it has ceased producing in other directions, the ration that such an animal would require would be equivalent to the ration required by a store animal in its early stage of fattening. The ratio of S.E. to D. P. in such a ration would be approximately 10.

To summarise, on an ordinary commercial farm, where the sizes of mature animals do not differ very much, all the milking animals and cows-in-calf yielding milk can fall under one group and would do well when supplied with the same type of concentrate mixture. Another type of mixture is required to be prepared for working bullocks and fattening animals both of which would fall under one group. Young animals on maintenance ration, and dry cows-in-calf, would probably get enough nutriment from home-grown fodders alone.

For the same mixture, weight or mass is proportional to volume. If therefore, different measures or containers—each being multiple of the other are kept on the farm, one has then simply to ascertain once the weight of a mixture filling the capacity of one of the measures to determine the correlation of measure to weight. This done, it will enable us to give so many measures for such and such animal instead of so many lbs. thus eliminating the necessity of weighing the mixture every day for each animal.

Purchasing the Cheapest Suitable Food.

Find out the deficit of S. E. and D. P. on the farm for each group of animals and determine their ratio. Then purchase some suitable and cheapest foodstuffs, among such foodstuffs whose ratios of S. E. to D. P. are narrower and some among those whose similar ratios are wider than the ratios in the deficit. Then find out the proportion in which these should be purchased as suggested above. Comparison of prices may be done on the basis of starch equivalents.

To be exact, however, in our estimate of valuation of a purchased foodstuff we cannot neglect to take into account its manurial value. This manurial value

should, therefore be deducted from the purchase price of the foodstuff in order to obtain the net value of starch equivalents contained in a unit weight of that foodstuff for feeding purposes. To find the manurial value of a feeding stuff, divide the percentage of protein by $6\frac{1}{4}$. This gives the percentage of nitrogen. Divide this by 2 to allow for the fact that half the nitrogen of a feeding stuff is usually lost in making F. Y. M. Multiply the figure so obtained by the present cost per unit of nitrogen in a ton of feeding stuff. Increase this figure by half to allow for the phosphate and potash. Thus :-

Let P=Protein per cent. and N=Cost per unit of nitrogen. According to the above we get the following :—

$$\left(\frac{P}{6\frac{1}{4}} \div 2\right) N + \frac{1}{2}\left(\frac{P}{6\frac{1}{4}} \div 2\right) N$$

$$= \frac{P \times 4 \times N}{25 \times 2} + \frac{P \times 4 \times N}{25 \times 2 \times 2}$$

$$= \frac{2PN}{25} + \frac{PN}{25}$$

$$= \frac{3PN}{25} = \text{manurial value of a feeding stuff.}$$

On live stock concerns, however, which mostly depend on the purchased foodstuffs—such as most of the dairies in Bombay and other big cities determination of manurial value should not be done according to this formula but rather according to the market price likely to be realised for the quantity of manure produced through freeding the foodstuff.

Reducing the cost of production of home-grown food.

This should mean growing not exactly the larger quantity of a crop or its products per unit value of money spent, but rather the total quantities of starch equivalents contained in these. The basis of starch equivalents should be enough ordinarily to evaluate the productivity of a crop without taking into consideration the total digestible proteins. Because, starch equivalent of a foodstuff is in the first place an index of thermic or energy as well as productive value not only of digestible carbohydrates and fats but also that of the digestible protein included therein. Hence it is not necessary to take separate count of the latter. Secondly in all well balanced schemes, deficiency of digestible protein is seldom felt unless the concentrates rich in proteins such as oil seeds are sold off the farm. Hence if you take care of the S. Es., D. Ps. will take care of themselves. To compare,

therefore, the cost of production of home grown foodstuffs on starch equivalent basis, find out the cost per lb. of S. E. or per unit of S. E. thus :—

Cost of production per lb. S.E. =

$$\frac{\text{cost of production per acre} \times 100}{\text{yield per acre in lbs.} \times \text{S.E. per hundred lbs.}}$$

Cost of production per unit of S.E.=Cost of production per lb. S.E.×22·4.

The former figure, *viz.*, the cost of production per lb. S.E. is particularly useful in assessing the cost of daily ration which is reckoned in lb. S.E., while the latter, *viz.*, the cost of production per unit of S.E. being larger is more convenient to use when we wish to compare the net productive values per acre of different crops to be grown on the farm.

If we desire, however, to obtain figures that would present more correct picture of crop valuation we cannot afford to neglect to take into account the value of protein as flesh former, in addition to its function of producing endothermic energy and fat in an animal body. Protein gives 23 p.c. more energy and 6 p. c. less fat in an animal body than an equal amount of carbohydrates. But as flesh former it cannot be compared with either carbohydrate or fat, because this quality is more or less exclusively possessed by protein alone. and therefore its value cannot be compared with the above nutrients on any definite basis. Its presence is absolutely much more essential for a young growing animal or an animal yielding milk than a working or fattening animal. Within certain limits protein can replace the other two nutrients in the matter of production of energy or fat which are the only nutritive functions of the latter, but it cannot itself be replaced by any one of these when the main production is the formation of flesh including bones. Of the foodstuffs containing equal amount of S.Es. the value of one containing greater amount of digestible proteins should necessarily be higher than the other. Then again, just as in the case of the soil which is not subjected to judicious cropping scheme, nitrogen often operates as a limiting factor to the satisfactory growth of a crop, so also nitrogen (protein) is liable to be deficient in foodstuffs grown on live-stock farms where the cropping scheme is too badly framed to allow of nutrients being produced in balanced proportion. It is obvious that anything that has got a tendency to constitute a limiting factor should command a greater value than its compliments whose value should, therefore, necessarily be lower. Hence digestible proteins and digestible fats are considered to be equal in value on an arbitrary basis, while each of these is taken to be 2·5 times more valuable than an equal weight of digestible carbohydrates. Comparative values of foodstuffs grown on the farm on the basis of different values for different kinds of digestible nutrients or "Food units" system as it is called may therefore be obtained thus.

Dig. Food units per 100 lbs. foodstuff :—

(Dig. Protein + Dig. Fat) 2·5 + Dig. Carbohydrate.

Cost of production per digestible food unit :—

$$\frac{\text{cost of production per acre} \times 100}{\text{yield in lbs. per acre} \times \text{dig. food units per 100 lbs.}}$$

For the sake of comparison of nutritional values in terms of money, collection and tabulation of data as shown below should prove immensely useful :—

In the case of home grown food :—

Serial No.	Name of the crop	Average cost of cultivation per acre	Average yield in lbs. per acre	Starch equivalents		Cost of production			Remarks
				per 100 lbs. of the crop	per acre	per unit S. E. Rs. as. ps.	per lb. S.E. Rs. as. ps.	per food unit Rs. as. ps.	

In the case of purchased food :—

Serial No.	Name of the food-stuff	Manurial value per ton	S. E. per 100 lbs. of the food-stuff	D. P. per 100 lbs. of the foodstuff	Ratio S. E. / D. P.	Price per			Remarks
						Ton Rs. as. ps.	Unit S. E. Rs. as. ps.	lb. S. E. Rs. as. ps.	

Comparison in this way of home-grown foods as items influencing economy in animal production will enable us to judge which crops that are possible to grow on the farm would be more profitable than others when included in the cropping scheme. There are, however, several other merits that need be taken into consideration, most important of which being, presence of sufficient amount of mineral matter, vitamine contents, a great variety of amino-compounds composing proteid matter, desirable taste and aroma that lend palatability, and absence of deleterious ingredients that would either affect the growth and health of the animals or the quality and quantity of their products. The choice of a crop to be put under cultivation, however, cannot be determined only on the basis of individual merits mentioned above, but as a component of a rotation,

the inclusion of the selected crop should on an aggregate increase the utility of a cropping scheme as a whole. For this purpose it needs not necessarily be the best and foremost in possessing the above attributes, if it allows only inferior type of crops to precede or follow as a course of rotation. By utility of a cropping scheme is meant not only its productivity but also its value of supplying succulents, roughages as well as concentrates more or less uniformly in due quantities throughout the year. Hence comparison of home-grown foods cannot be made on the wholesale basis but rather should be done separately among each group, *viz.*, succulents with succulents, roughages with roughages, while concentrates with concentrates.

It is ideal to feed succulents in fresh condition at all times of the year, if that is possible. But this object is unattainable in India where the natural precipitation is confined only to 3 or 4 months in the year, except in tracts where irrigation facilities exist. The crops that may be selected to form a rotation should therefore allow of preserving or storing a part of the plants or their products in succulent condition either as silage or as roots. The value of succulents lies in their high palatability, low fibre contents, richness in vitamins of nearly all types and high mineral contents in more or less balanced proportion. And since each of these four factors tend to increase the digestibility of a feeding stuff, the digestion coefficient of succulents is rather high, nay, there are evidences to show that the latter tends to go high even in the case of foodstuffs that are fed in conjunction with succulents in a mixed ration. The value of hay in respect to possessing these merits comes somewhere between roughages such as *kadbi* and succulents and, indeed, better types of hay behave more like succulents than roughages. Likewise, concentrates resemble succulents except that former are slightly less palatable and the mineral matter that they contain, though high, are not generally in a balanced proportion, there being often preponderance of P_2O_5 over CaO, instead of these occurring in more or less equal proportion. Besides, many concentrates, though not all, are deficient in some of the vitamins.

Our main efforts should be directed towards reducing the cost of production as much as possible, as there is more room to effect economy in this way than perhaps in any other way. This may be brought about by using labour saving devices, supplying the right type of fertilizers in optimum amounts and at right times, increasing the humus contents of the soil, following rotation that would increase the productivity of the farm and allow of labour being exploited or utilised fully throughout the year. Where growing of grasses is possible, system of rotational grazing has been proved to give the best resuts per unit amount of capital spent. Mineral matter such as superphosphates for grasses have the property of not only

increasing the total amount of food units but also improving the quality of the pasture by increasing its mineral contents and digestibility. In fact it forms a most economical plant to exterminate coarse and innutritious fodder which is smothered down by the luxuriant growth of nutritious type of fodder.

Correlation of the cost per lb. S. E. to net profits will serve a useful guide in stipulating net returns from a livestock farm. On a whole-milk selling dairy farm such correlation can be determined for example as follows :—

Find out first the average (*a*) live weight (*b*) milk yield in lbs. and (*c*) fat percentage per animal. Then by means of these data determine the number of S. Es. required for this average animal for its daily ration. If by feeding n lbs. of S.E., m lbs. of milk are obtained, then 1 lb. S.E. will give $\frac{m}{n}$ lbs. of milk. If the selling price per lb. of milk is p, and the transportation cost per lb. milk is t then each lb. S.E. will fetch a price in the market equivalent to $\frac{m(p-t)}{n}$. This, therefore represents the gross returns per lb. S.E.

If c represents the cost of production per lb. S.E. and since $\frac{2}{3}$rd to $\frac{3}{4}$th of the total cost of production is due to feed charges, it may safely be taken that to obtain $\frac{m(p-t)}{n}$ gross income, the former shall have to spend between $\frac{3}{2}$ c to $\frac{4}{3}$ c. To err on the safe side let us assume the higher figure *viz.*, $\frac{3}{2}$ c. This has to be deducted from gross returns $\frac{m(p-t)}{n}$ to obtain net returns per $\frac{3}{2}$ c. To obtain the percentage net returns, the net returns per $\frac{3}{2}$ c has to be multiplied by 100 and divided by $\frac{3}{2}$ c. Hence the following formula may be used to stipulate the percentage of net returns on a milk selling dairy concern where the management and feeding are carried on up to-date scientific principles :—

$$\text{Percentage net returns} = \left(\frac{m(p-t)}{n} - \frac{3}{2}c\right)\frac{100}{\frac{3}{2}c} = \frac{66\,m(p-t)}{nc} - 100$$

$$= \frac{\%\text{ of food expenses in total expenses} \times m(p-t)}{nc} - 100,$$ where m—milk yield in lbs., p—price per lb. of milk, t the cost of transportation per lb. of milk, n number of S. Es. required daily for the average type of animal, and c—cost of production per lb. S. E.

From this equation we are also able to find out the cost of production per lb. S. E. to correspond to certain desired figure of percentage net returns, thus :—

$$c = \frac{66\,m(p-t)}{n(\%\text{ net returns} + 100)}$$

Example (1)—In a herd of dairy animals the following are the average figures per cow : live weight 1000 lbs., milk yield 12 lbs. and butter fat percentage 4. If the cost per lb. S. E. is 2 annas, price obtained per lb. milk is 3 annas, and transportation charges per lb. milk are 3 pies, what should be the stipulated net profit ?

$$n=\frac{\text{Lw}}{250}+2+\left(\frac{m\times\text{ fat }\%}{16}\right)=9$$

$$\text{net profit}=\frac{66\,m\,(p-t)}{nc}-100=21.$$

Example (2)—On the above dairy farm, how far should the cost of production per lb. S. E. be brought down in order to obtain 32% net profit ?

$$c=\frac{66\,m\,(p-t)}{n\,(\%\text{ net profit}+100)}=\frac{66\times12\times11}{4\times9\times132}=1\text{ a. and 10 pies.}$$

Example (3)—Find the cost of production per lb. S. E. on the above dairy farm when it shows neither profit nor loss.

$$c=\frac{66\,m\,(p-t)}{n\,(0+100)}=\frac{66\times12\times11}{4\times9\times100}=2\text{ as. and 5 pies.}$$

On this farm therefore if the cost of production per lb. S. E. is 2 as. and 5 pies, the profit is nil.

Example (4)—When the state of the above farm is such that it yields neither profit nor loss, if a breeder increases the milk yield by 100% or twice the original amount, (without attempting to reduce the cost of production per lb. S. E.) what would be his stipulated percentage net returns ?

$$n=\frac{\text{Lw}}{250}+2+\left(\frac{m\times\text{fat}\%}{16}\right)$$

$$=\frac{1000}{250}+2+\left(\frac{24\times4}{16}\right)$$

$$=6+6=12$$

$$\text{percentage net returns}=\frac{66m(p-t)}{nc}-100=\frac{66\times24\times11}{4\times12\times\frac{121}{50}}-100$$

$$=\frac{66\times24\times11\times50}{4\times12\times121}-100$$

$$=50.$$

Now 50 per cent. net returns can be had either by reducing the cost of food by 20% or else by increasing the milk yield per animal by 100% in the above case. Attempting to effect economies, however by the former process is certainly much easier and gives the desired results far more quickly when compared with the latter process which is less certain and indeed takes considerably longer time of careful selection and breeding.

EVOLVING STRAINS OF ANIMALS OF BETTER YIELD BY SELECTION AND BREEDING.

Breed the best to the best should be the motto in practice of a live-stock farmer. It otherwise means rigorously putting a stop to any further breeding of such animals as do not come up to a certain desired standard or, in other words, do not pay satisfactorily. Selection of the best and elimination of the unsatisfactory for breeding purposes, that is to say, grading up high producing stock by the use of pedigree bulls, will gradually but continuously raise the productivity of the herd. To achieve this end in practice, it involves the adoption of the following procedure :—

(1) Watching and maintaining the record of performance of each individual animal as a producer, breeder as well as early maturer.

(2) Maintaining the pedigree record in order to be able to trace ancestral performance.

(3) Introducing, if need be, a pedigree bull of noteworthy performance or individual merit which should also possess prepotency or the ability to breed true to its character.

(4) Sufficiently early castration of condemned male animals.

While making selection of individuals of a herd we are mainly guided by three considerations, *viz* :—

(1) *Ancestral record or pedigree*—this when rationally used forms a valuable aid to the breeder in his work of selection. This test, however, when used singly or by itself, does not lead us far in giving true estimate of the value of an animal but when used in conjunction with

(2) *Individual merit*—undoubtedly proves a valuable guide. Similarly being guided by the basis of individual record alone will be of little avail unless we take into consideration the average merit of the animal's immediate ancestors. The two taken in conjunction would undoubtedly prove a far better guide than either considered alone. Pedigree gives the idea of potentialities of characters being transmitted, while the individuality gives evidence as to how far these potentialities have expressed themselves into reality. The third test which is by far the

most important and comprehensive is

(3) *Genotypic selection*—this is based upon actual breeding ability as determined by tests. This test exposing, as it does, to light the genotypic constitution of the animal concerned gives much clearer estimate of the hereditary characters than the above tests either singly or taken together. But this test, in the slow breeding species like cattle, limits itself in practice to be applied to the male sex only. It is by far the best plan therefore to subject a breeding bull to this test by mating him with about a dozen of cows possessing recessive characters. If the bull is homozygous for the dominant character in question all his progeny will show the dominant character, the latter being heterozygous. But if he is heterozygous fifty per cent. of his progeny should come out heterozygous showing the dominant character and the remaining fifty per cent. should show the recessive character being homozygous for the recessive character. With so small a number as about a dozen we cannot hope to expect the theoretical 50 : 50 ratio, but we may take it as certain that if even one of his progeny shows recessive character, we are not dealing with a pure blooded or homozygous bull but a cross which will introduce heterogenieity into the herd of his progeny. If, however, all the progeny without a single exception go after their father, the latter is probably a pure blooded animal and as such safe to be retained in the herd for the purpose of breeding.

In India where cattle are generally unfenced and let loose without any supervision, it is but imperative to have a keen guard against wanton breeding of undesirable animals. There are in the main two sources that constitute danger from the point of view of destructive breeding. One of these is an animal which is mature enough to breed, but according to prevailing custom, not yet sufficiently grown up to be castrated. In fact it seems that their sole aim of castration is to tame the animal and get him in a condition fit to work rather than stop indiscreet breeding. The other source comes from Brahmini bulls. It is more than probable that the original purpose of the practice of presenting a bull to a god or goddess lay in dedicating an animal of more than average standard to the service of agricultural community just as now the department of agriculture is doing by presenting a premium bull to a responsible society. But unfortunately now-a-days the system has degenerated into mere formality wherein the original purpose is lost sight of, and an animal of any type may be selected for the purpose irrespective of its pedigree, individual merit, or genotypic constitution or prepotency. Hence we should at once try either to put a stop to this sort of destructive breeding or else modify or improve upon it. This may best be done by enacting an ordinance by which all male animals must perforce be castrated sufficiently early except those

that are certified or registered as fit for breeding purposes by a committee of inspectors, experts or select members of a breeders association responsible to maintain a high standard of a specific breed.

There is a boom among certain breeders that one of the best solutions to improve the productive capacity of Indian cattle which is at present, no doubt, inferior, would lie in adopting the practice of crossing either among prominent Indian breeds or else by introducing foreign breeds. But this presumption is fallaceous. Many authorities declare that we have in India breeds of cattle par excellent as possessing potentialities to produce much higher than the present average and combining almost all the desirable characters for the purpose of specific production within a single well defined breed, without the necessity of resorting to introducing or incorporating any other good character *de novo*. Our job lies for the present in activating the productive capacity of a breed to the highest level a breed is capable of reaching, and breeding out any bad characters that its individuals may possess, and this means nothing more than grading up of animals as suggested above, followed by fixing the resultant type attained in this way and finally having recourse to in breeding. It should, however, be well remembered that no amount of selective breeding will prove of any great value unless the animals are supplied with the requisite amount of food of proper quality and maintained under efficient management; otherwise the results that may be obtained would be misleading, because a high producing strain of animal usually being more sensitive to different treatments is likely, under bad management and insufficient or malnutrition to suffer proportionately more in its production than an ordinary type of animal which can weather rough and untoward circumstances.

The writer does not contend to say that the importation of foreign blood will not increase the productivity of an Indian herd. There are instances where the importation of foreign blood has raised the standard of production of a herd to a considerable extent, but such practices have also been responsible to introduce foreign diseases, as well as to render the resultant crosses more susceptible to more or less specific Indian diseases, a state of affairs that should prove highly detrimental to the live-stock industry in this country at least for decades or centuries to come till immunity finally comes to stay in their blood.

THE BIOLOGICAL NATURE OF THE VIRUSES*

BY

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The viruses are a group of agents, the existence of which would certainly be unknown to us but for the changes produced by their presence in the bodies of higher animals and plants. They seem to have one property at least of living organisms, in being capable, under appropriate conditions, of indefinite reproduction. We know nothing of their intrinsic metabolism: it has even been asserted that they have none. Few of them have yet been rendered visible by the microscope; it is, indeed, a question for our discussion whether any of them have yet been seen or photographed. It is a question, again, whether any of them, or all of them, consist of organised living units, cells of a size near to or beyond the lowest limits of microscopic visibility; or whether, as some hold, they are unorganised toxic or infective principles which we can regard as living in a sense analogous to that in which we speak of a living enzyme, with the important addition that they can multiply themselves indefinitely. Some however, would attribute this, not to actual self-multiplication, but to a coercion of the infected cells to reproduce the very agent of their own infection.

The problems presented by the nature and behaviour of the viruses cannot fail to raise questions of the greatest interest to anyone concerned with general physiological conceptions. What is the minimum degree of organisation which we can reasonably attribute to a living organism? What is the smallest space within which we can properly suppose such a minimum of organisation to be contained? Are organisation, differentiation, separation from the surrounding medium by a boundary membrane of special properties, necessary for the endowment of matter with any form of life? Or is it possible to conceive of a material complex, retaining in endless propagation its physiological character, as revealed by the closely specific reaction to it of the cells which it infects, though it is not organised into units, but uniformly dispersed in a watery medium? Among those who study the viruses primarily as pathogenic agents, these questions provide matter for debate;

* From the Presidential Address introducing a discussion on the subject in Section I (Physiology of the British Association in London on September 28, 1931.

I suggest that they are questions with which the physiologist may properly be concerned.

I cannot deal with the history of the subject; but it is of interest to note that Edward Jenner was dealing, in small-pox and vaccinia, with what we now recognise as characteristic virus infections, long before there was any hint of the connexion of visible bacteria with disease. Pasteur himself was dealing with another typical case of a virus infection in the case of rabies. The clear recognition, however, of the existence of agents of infection, imperceptible with the highest powers of ordinary microscopic vision, and passing through filters fine enough to retain all visible bacteria, begins with Ivanovski's work in 1892 on the mosaic disease of the tobacco plant, brought to general notice and greatly developed by Beijerinck's work on the same infection some seven years later; and with Loffler and Frosch's demonstration, in the same period, that the infection of foot-and-mouth disease is similarly due to something microscopically invisible, and passing easily through ordinary bacteria-proof filters. Since those pioneer observations the study of viruses has spread, until they are recognised as the causative agents of diseases in an imposing and still growing list containing many of the more serious infections of man, animals, and plants.

If we are to discuss the biological nature of the viruses, it is obvious that we should begin by attempting some kind of definition. What do we mean by a virus? And what are the tests by which we decide that a particular agent of infection shall be admitted to, or excluded from, the group? But a few years ago I think that we should have had no difficulty in accepting three cardinal properties as characterising a virus, namely, invisibility by ordinary microscopic methods, failure to be retained by a filter fine enough to prevent the passage of all visible bacteria, and failure to propagate itself except in the presence of, and perhaps in the interior of, the cells which it infects. It will be noted that all three are negative characters, and that two of them are probably quantitative rather than qualitative.

Such a definition is not likely to effect a sharp or a stable demarcation. We shall see that its failure to do so is progressive. Nevertheless it would still be difficult to refuse the name of virus to an agent which fulfils all three criteria; and we must therefore, in consistency, apply it, on one hand, to the filterable agents transmitting certain tumours, and, on the other hand, to the agents of transmissible lysis affecting bacteria, and now widely known and studied as bacteriophages. But the strict application of such a definition, based on negative characteristics, must obviously narrow its scope with the advance of technique. We may look a little more closely at the meaning of these different characters.

Microscopic visibility is obviously a loose term. Rayleigh's familiar formula, in which the lower limit of resolution is equal to one-half the wave-length of the light employed, divided by the numerical aperture of the objective, only gives us the smallest dimensions of an object, of which, with the method of transmitted illumination habitually used in former years, a critical image can be formed. There can be no doubt that the separate particles of practically all the agents to which the term virus would be applied fall below this limit of size. To put it in plain figures, their diameter is less than 0·2 micron. On the other hand, progress has recently been, and continues to be, rapid in the direction of bringing into the visible range minute bodies associated with a growing number of viruses. This has been effected, on one hand, by improvement in staining technique, which probably owes its success largely to increase of the natural size of the particles by a deposit of dye on their surface; and on the other hand, by forming visible diffraction images of the unstained particles with wide-aperture dark-ground condensers, and by photographing the images formed of them with shorter invisible rays. Mr. Barnard has obtained such sharp photographic images of the bodies associated with one virus, measurements of which give their natural size by simple calculation.

The reaction of a cautious criticism to such a demonstration seems to have taken two different directions. There has been a tendency, on one hand, to exclude an agent from the group of viruses as soon as the microscope could demonstrate it with some certainty. Many have for years thus excluded the agent transmitting the pleuro-pneumonia of cattle, though the status of this organism has been compromised even more by the success of its cultivation on artificial media. Visibility seems to have rendered doubtful the position of the Rickettsia group of infections, and, if the test is logically applied, the process of exclusion can scarcely stop before the agents transmitting psittacosis, fowl-pox, infectious ectromelia, and even vaccinia and variola, have been removed from the group of viruses into that of visible organisms.

In discussing the biological nature of viruses as a whole, however, we can scarcely begin by accepting an artificial and shifting limitation of that kind. The real task before us, rather, is to discuss to what extent the evidence of these recent developments, which appear to show that some of the agents, known hitherto as viruses, consist of very minute organisms, can safely be applied to other viruses which are still beyond the range of resolution. Do these also consist of organisms still more minute, or are any of them unorganised? Another line of criticism, sound in itself, while not excluding from the virus group these agents for which microscopic visibility has been claimed, demands more evidence that the minute

bodies seen or photographed are really the infective agent, and not merely products of a perverted metabolism which its presence engenders.

It is obvious that complete evidence of identity cannot be obtained until a virus has been artificially cultivated in an optically homogenous medium. Meanwhile it is a question of the strength of a presumption, on which opinions may legitimately differ. Let us recognise that the evidence is not perfect, but beware of a merely sterilising scepticism. I suspect that the attitude of some critics is coloured by past history of the search for viruses and especially by that part of it concerned with the curious objects known 'as inclusion bodies', which are readily demonstrated with relatively low powers of the microscope, in the cells of animals and plants infected with certain viruses. From the earlier and admittedly hasty tendency to identify them as infective protozoa, opinion seems to have swung too quickly to the opposite extreme, of dismissing them as mere products of the infected cell. It is so comparatively simple, in some cases, to separate these bodies, that it is surprising that so few efforts have been made to test their infectivity. However, the power of such a body to convey at least one virus infection has been demonstrated; and since they have further been shown, in several cases, to consist of a structureless matrix packed with bodies looking like minute organisms, the burden of proof in other cases seems to me, for the moment, to rest on those who suggest that they consist wholly of material precipitated by the altered metabolism due to the infection.

The physical evidence, obtained by filtration through porous fabrics and colloidal membranes and by measuring rates of diffusion, is, of course, purely concerned with the size of the units of infective material, and must be taken in conjunction with the evidence provided by the microscope. The crude qualitative distinction between the filterable and non-filterable agents of infection has long since ceased to have any real meaning. There is no natural limit of filterability. A filter can be made to stop or to pass particles of any required size. It is now realised that the only proper use of a filter in this connexion is to give a quantitative measure of the maximum size of the particles which pass it. Evidence from failure to pass must always be subject to correction for the effects of electrostatic attraction and fixation by absorption on the fabric of the filter. A large amount of filtration evidence has, further, been vitiated by reliance on determinations of the *average* pore size of the filter. In dealing with an infective agent, the test for the presence of which depends on its propagation under suitable conditions, it is obviously the maximal pore size which is chiefly significant.

For these reasons a good deal of the evidence showing that certain viruses can be detected in the filtrates, obtained with filters which will not allow haemoglobin

to pass in perceptible quantities, must be regarded at least with suspicion. Dr. Elford has recently succeeded in preparing filter-membranes of much greater uniformity, with a small range of pore-diameters. His measurements with these, of the sizes of the particles of different viruses, show a range approaching the dimensions of the smallest recognised bacteria, on one hand, and falling as low, in the case of the virus of foot-and-mouth disease, as about three or four times the size of the haemoglobin molecule; the latter being given not only by filtration-data, but also by other physico-chemical measurements, such as those obtained by Svedberg with the ultracentrifuge. It should be noted, as illustrating the difficulties of the problem and the uncertain meaning of some of the data, that Elford has regularly found a bacteriophage to be stopped by a membrane which allows the foot-and-mouth virus to pass; while, on the other hand, recent determinations of the rate of diffusion of bacteriophage, made by Bronfenbrenner, put the diameter of its particles at 0·6 of a millimicron, that is, only about one-fifth of the accepted dimensions of the haemoglobin molecule. If we accepted such an estimate, we should be obliged to conclude, I think, not merely that the bacteriophage is unorganised, but that its molecules are something much simpler than those of a high-molecular protein. It has even been suggested, though on very imperfect evidence, that it may be a moderately complex carbohydrate. Are we, then, to suppose that the foot-and-mouth virus is a similarly unorganised and relatively simple substance? It is difficult to do so, in view of the series of other agents, all conforming in many aspects of their behaviour to the classical type of the foot-and-mouth virus, and yet showing a range of dimensions up to that at which their units are apparently becoming clearly visible by modern microscopical methods.

It will be clear, indeed, that, if we accept the lowest estimates for the size of the units of some viruses, such as the bacteriophage and the agents transmitting some plant diseases, we cannot by analogy apply the conception of their nature, thus presented, to viruses consisting of organisms which are ceasing to be even ultramicroscopic; and we should be led to doubt the identity with the virus of the bodies which the microscope reveals. If, on the other hand, we regard the still invisible viruses, by analogy with those already seen, as consisting of even much smaller organisms, we can only do so by rejecting the conclusions drawn from some of the physical evidence. It is, of course, possible that some of the agents called viruses are organisms and other relatively simple pathogenic principles in solution; but to assume at this stage such a fundamental difference, among members of a group having so many properties in common, would be to shirk the difficulty.

The third negative characteristic of a virus, namely, its failure to propagate itself, except in the presence of living cells which it infects, may obviously again

provide an unstable boundary, shifting with the advance of our knowledge and skill. We may regard it as not only possible, but even likely, that methods will be found for cultivating artificially, on lifeless media, some of those viruses at least which have the appearance of minute organisms. It would be playing with nomenclature to let inclusion in the virus group depend on continued failure in this direction. On the other hand, the dimensions assigned to the units of some viruses, representing them as equal in size to mere fractions of a protein molecule, might well make one hesitate to credit them with the power of active self-multiplication. Experience provides no analogy for the growth of such a substance by self-synthesis from the constituents of a lifeless medium; the energetics of such a process might present an awkward problem. To account for the multiplication of such a substance at all, even in cells infected by it, we should be driven, I think, to the hypothesis which has been freely used to account for the propagation of bacteriophage, on one hand, and of typical viruses like that of herpes, on the other; namely, that the presence of the virus in a cell constrains the metabolism of the cell to produce more.

Bordet has used the reproduction of thrombin by the clotting of the blood as an analogy for the suggested reproduction of bacteriophage in this manner. Another, and perhaps closer, analogy might be found in recent evidence that a culture of pneumococcus, deprived of its type-specific carbohydrate complex, can be made to take up the carbohydrate characteristic of another type, and then to reproduce itself indefinitely with this new artificially imposed specificity. The response of the cells of the animal body to even a single contact with a foreign protein, by the altered metabolism producing immunity, and often persistent for the lifetime of the individual, may suggest another parallel; but here the protective type of the reaction is in direct contrast to the supposed regeneration by the cells of the poison which killed them.

Boycott, again, has emphasised the difficulty of drawing a sharp line of distinction between the action of normal cell-constituents, which promote cell-proliferation for normal repair of an injury, and the virus transmitting a malignant tumour, or that causing foot-and-mouth disease. I do not myself find it easy, on general biological grounds, to accept this idea of a cell having its metabolism thus immediately diverted to producing the agent of its own destruction, or abnormal stimulation. It is almost the direct opposite of the immunity reaction, which is not absent, but peculiarly effective in the response of the body to many viruses. It is difficult, again, to imagine that a virus like rabies could be permanently excluded from a country if it had such an autogenous origin. The phenomena

of immunity to a virus, and of closely specific immunity to different strains of the same virus, are peculiarly difficult to interpret on these lines.

This conception, however, of the reproduction of a virus by the perverted metabolism of the infected cell has been strongly supported by Doerr, in explanation of the phenomena of herpes. There are individuals in whom the epidermal cells have acquired a tendency to become affected by an herpetic eruption, in response to various kinds of systemic or local injury. From the lesions so developed, an agent having the typical properties of virus can be obtained, capable of reproducing the disease by inoculation into individuals, even of other species, such as the rabbit, and exciting, when appropriately injected, the production of an antiserum specifically antagonising the herpes infection. Such phenomena have a special interest for our discussion, in that they can be almost equally well explained by the two rival conceptions. One regards the herpes virus as a distinct ultramicroscopic organism, and the person liable to attack as a carrier, in whom the virus can be awakened to pathogenic activity and multiplication by injuries weakening the normal resistance of his cells to invasion. The other regards it as a pathogenic principle produced by cells in response to injury, awakening other cells to further production when transmitted to them.

This forms a good example of the central difficulty in dealing with the group of agents at present classed together as viruses. They seem to form a series; but we do not know whether the series is real and continuous, or whether it is formed merely by the accidental association, through a certain similarity in effects, and through common characteristics of a largely negative kind, of agents of at least two fundamentally different kinds. If we approach the series from one end and watch the successive conquests of microscopical technique, or if we consider the phenomena of immunity over the whole series, we are tempted to assume that all viruses will ultimately be revealed as independent organisms. If we approach from the other end, or consider analogies from other examples of a transmissible alteration of metabolism, we may be tempted to doubt the significance of the evidence provided by the microscope, and to conclude that all viruses are unorganised, autogenous, toxic principles. If we take the cautious attitude of supposing that both are right, and that viruses belonging to both these radically different types exist, where are we going to draw the line? Is the test to be one of unit dimension? If so, what is the lower limit of the size of an organism? Are we to suppose that inclusion bodies can only be produced by viruses which are independent organisms? And if so, does this conclusion also apply to the 'X' bodies associated with the infection of plant cells by certain viruses?

If we try to form an estimate of the lower limit of size compatible with organisation, I think we should remember that particles which we measure by filters of known porosity, or by photomicrographs, need not be assumed to represent the virus organisms in an actively vegetative condition. They may well be minute structures, adapted to preserve the virus during transmission to cells in which it can resume vegetative life. Attempts to demonstrate an oxidative metabolism in extracts containing such virus, separated from the cells in which it can grow and multiply, and to base conclusions as to the non-living nature of the virus on failure to detect such activity, must surely be regarded as premature.

Our evidence of the vitality of its particles is, as yet, entirely due to their behaviour after transmission. They may accordingly contain protein, lipoid and molecules in a state of such dense aggregation that comparisons of their size with that of the heavily hydrated molecules of a protein in colloidal solution may well give a misleading idea of their complexity.

Apart from their known function as the agents transmitting many of the best known among the acute infections, it is impossible, to any one having even a slight knowledge of the recent developments which began with the work of Rous and Murphy, to doubt that in the advance of knowledge concerning the nature of the viruses in general lies the brightest hope of finding a clue to the dark secret of the malignant tumours. In unravelling what is still such a tangle of contradictions, the animal biologist needs all the help that can be given by concurrent study of the analogous phenomena in plants.

RESULTS OF THREE YEARS' STUDY OF CERTAIN POULTRY RATIONS AS THEY AFFECT THE HATCHING POWER OF HEN EGGS AS WELL AS THE NUMBER OF EGGS LAID.

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The Province of Ontario loses annually many thousands of dollars through poor hatches during incubation. In our modern types of incubators with their controls for temperature, ventilation and moisture, there are still about forty per cent. of the eggs set never hatch a chick. Poor hatches are put down to a number of causes. Too often, however, when the hatch is low people are inclined to find fault with the incubator. It seems quite safe to state that the majority of incubators in use to-day will give reasonably good results, providing the eggs are set from a well managed flock and the operator performs his or her duties faithfully during the period of incubation. Good management is the secret to success. It involves the care of the breeding flock; the selection of the breeding of the birds used; especially that of the males; the feeding methods and kind of rations used; the sanitation as carried out together with such things as the handling of the hatching eggs. It is possible to so manage the flock during the winter months that more eggs may be gathered; such eggs when set to give as many chicks as the same number would if set in July.

It is hoped that the data submitted may be of service to those who wish to produce a good hatchable egg.

Much experimental and research work has been done and is in progress at the present time on the use of the various kinds of proteins, vitamins and minerals, on both the growing chick and the laying hen. Through the use of Cod Liver Oil—a rich source of vitamin D, feeding methods have changed somewhat during the past few years. There is considerable evidence to show the beneficial effect of Cod Liver Oil on hatchability, egg production and the general health of the flock. The diet fed the parent fowl appears to have a very definite effect on egg production and hatchability.

PLAN OF EXPERIMENT.

The general plan of the experiment was to study the influence of such animal proteins as Milk, Fish Scrap, Beef Scrap and Tankage as they might affect hatch-

ability and egg production. These materials were used as a sole source of protein in the rations and, in addition, were fed in combination with Milk, with or without Cod Liver Oil. The experiments consider two main points.

1. The effect of certain animal proteins on the hatchability of hen's eggs.
2. The effect of the amount and quality of sunshine on the hatchability of hens' eggs.

It is generally believed that the hatching power of eggs is an inherited character and might very well be considered to be an equally important factor. The birds used in the experimental trial are all of known ancestors and come from the general pedigree pens of the Department. Their ancestors are known for ten years or more together with their record of performance. This information may help materially in the final study of the problem.

The incubator used was a six thousand egg Petersime machine, which makes it possible to set all eggs daily for the entire period. This insures that all eggs are set the day they are laid and that every egg is under the same external conditions during incubation.

Twenty Barred Rock pullets and one male as nearly equal in age and breeding as possible, are used in each pen. All pullets used in the experiment were hatched in late March and early April. It is generally conceded by Ontario poultrymen that April hatched Barred Rocks give a lower hatch than those hatched in February or March. The males are rotated from pen to pen daily. Pullets are used in preference to hens in that their eggs are likely to be a little more difficult to hatch, other things being equal.

In case of a death of a bird, it is immediately replaced by a bird of similar breeding so that the pens are constantly kept up to strength.

It is planned to conduct the trial for five years which would give data on one hundred females on each ration being studied.

The individual pens are twelve feet wide and fourteen feet deep. There are two glass windows three feet by three feet six inches in each pen as well as two movable screens which may be opened on days when the weather permits. The screens are twenty inches square. One is covered with cheese cloth and the other is covered with cel-o-glass. The trapnests, drinking fountains, pans, feed hoppers are the same size in each pen. There should be little or no difference between the pens.

The Method of feeding and management.

In view of the many factors that may affect production and also hatchability a system of feeding and management has been developed to control as many of

these as possible on a measurable basis. With this in mind, the following feed schedule was followed :—

A. M.—A light feed of grain scattered in the litter.

Noon—A portion of the mash for each pen is fed moistened.

The Cod Liver Oil is fed in this mash daily.

P.M.—A heavy feed of grain was fed in troughs.

N.B.—No artificial lights were used.

The mash for each pen is fed in hoppers and is available for the bird to eat throughout the entire day.

All birds confined to the pen for the entire eleven months.

RATIONS FOR EXPERIMENTAL PENS.

BASAL MASH TO ALL PENS	WHOLE GRAIN MIXTURE
700 lbs. Corn Chop	50 lbs. Yellow Corn
500 lbs. Wheat Shorts	50 lbs. Wheat
300 lbs. Oat Chop	Daily amount to each pen—
10% Alfalfa Meal	A.M.—½ lb. in litter
2½% Bone Meal	P.M.—2 lbs. in hopper
½% Salt	

To the dry mash, kept in front of the birds all the time, was added the following,—

PEN	AMOUNT AND KIND OF PROTEIN	OTHER ADDITIONS
2	10% B.M.P. (Buttermilk Powder)	U.V.L. (Irradiation)
4	10% B.M.P.	Cod Liver Oil
6	5% B.M.P. + 7½% Fish Scrap	
8	5% B.M.P. + 7½% Fish Scrap	Cod Liver Oil
10	5% B.M.P. + 10% Beef Scrap	Cod Liver Oil
12	5% B.M.P. + 10% Tankage	Cod Liver Oil
18	20% Beef Scrap	Cod Liver Oil
20	10% B.M.P.	
22	20% Beef Scrap	
24	20% Tankage	
26	15% Fish Scrap	
28	15% Fish Scrap	Cod Liver Oil
30	20% Tankage	Cod Liver Oil
32	37% B.M.P.	Cod Liver Oil

N.B.—U.V.L. (Ultra Violet Light) half hour irradiation daily except Sunday.
C.L.O. (Cod Liver Oil) 20 cc. daily to each pen in moist mash.

In addition to the dry mash, birds have free access to oyster shell, grit and water at all times. The weighed quantity of grain, 2½ lbs. per pen per day, was fed on an assumed ratio 50 : 50 mash to grain consumption. By this method any variation in food consumption was measured by the amount of dry mash and oyster shell eaten.

The protein supplements were added on an equivalent basis to the basal mash, with the exception of Milk. Small quantities of the basal mash were weighed out in separate containers weekly and the animal proteins were added to the various groups.

A chemical analysis of each individual source of protein was determined. An equivalent quantity of Fish Scrap, Meat Scrap and Tankage was fed on the basis of their chemical analysis, as stated previously, with the exception of Milk, of which one half of the quantity by weight was used.

The feeding trials for 1929 and 1930 included two pens on a Milk diet; one pen the same as 1928, that is 10% of the mash of Buttermilk Powder and the other pen was given 37% of Buttermilk Powder or enough to equal the animal protein of the pens on Fish Scrap and Meat Meal.

Composition of the Rations.

In Table I is shown the percentage composition of representative samples of each of the protein supplements used in these experiments. Repeated analysis of different samples of the same protein concentrate showed that the composition might vary within fairly wide limits, for instance, the buttermilk consignments analysed varied in crude protein content from 29—35%. It was, therefore, necessary to make protein determinations on each new batch of feed and to increase or decrease the amount of the protein supplement in the ration so that the total protein was kept approximately the same throughout the entire experiment. The percentage composition of the mash fed to each pen is given in Table II and is calculated from the percentage composition of the ingredients of the mash (see Table I). To study the effect of adding Cod Liver Oil or Ultra Violet irradiation to the Buttermilk Powder rations, the total protein of those rations was kept approximately the same at 13·5% (*i.e.*, pens 2, 4 and 20). The total protein content of the rations planned to compare the different protein supplements with and without Cod Liver Oil (*i.e.*, pens 18, 22, 24, 26, 28, 30 and 32) was approximately 21%. In comparing the nutritional value of the combinations of these protein supplements (*i.e.*, pens 6, 8, 10 and 12) the total protein of the rations was approximately 18%.

TABLE I.

Percentage composition of protein supplements.

	Meat Scrap	Tankage	Fish Meal	Butter-milk Powder	Semi-solid Butter-milk	Basal Mash
Moisture	3·84	5·89	5·90	7·62	71·25	9·82
Crude Protein (N × 6·25)	55·90	56·70	75·77	34·80	9·90	12·34
Ether Extract	14·58	10·01	3·86	5·31	1·65	4·78
Crude Fibre	1·22	1·79	·23	...	...	7·59
Lactose	...	...	...	37·91	10·90	...
Lactic Acid	...	...	...	5·82	4·60	...
Total Ash	10·51	20·28	17·63	8·47	1·90	4·95

70 lbs. ground Yellow Corn. 10% Alfalfa.
50 lbs. Shorts. 2·5% Bone Meal.
30 lbs. Ground Oats. 1% Iodized Salt.

TABLE II.

Percentage composition of the mash.

Pen	Ration	Crude Protein (N × 6·25)	Ether Extract	Crude Fibre	Total Ash
2	B.M.P. + Irradiation	13·6	4·7	6·8	5·3
4	10% B.M.P. + C.L.O.	13·5	6·7	6·7	5·2
20	10% B.M.P.	13·6	4·7	6·8	5·3
32	37% B.M.P. + C.L.O.	20·6	6·9	4·6	6·2
18	20% Meat Scrap + C.L.O.	20·8	8·7	6·1	7·8
28	15% Fish Scrap + C.L.O.	21·3	6·4	6·3	6·7
30	20% Tankage + C.L.O.	21·1	8·0	6·7	8·1
26	15% Fish Scrap	20·6	4·2	5·7	6·4
22	20% Meat Scrap	21·0	6·7	6·3	7·9
24	20% Tankage	21·2	6·0	6·4	8·0
10	5% B.M.P. + 10% Beef Scrap + C.L.O.	17·6	7·5	6·4	6·5
8	5% B.M.P. + 7½% Fish + C.L.O.	17·9	6·6	6·5	6·0
12	5% B.M.P. + 10% Tankage + C.L.O.	17·6	7·2	6·5	6·5
6	5% B.M.P. + 7½% Fish Scrap	18·2	4·7	6·7	6·2

**TABLE III.

Month	* Hours of sunshine	
February	100·2	389·8 hours
March	126·2	
April	163·	
May	246·1	823·1 hours
June	263·8	
July	313·2	

* Three years average.
** Data supplied by the Engineering Department, O.A.C.

The data in reference to the hatching power of eggs is based only upon the fertile eggs. All the eggs candled out as infertiles during incubation were broken for an examination of the germ inside. A small percentage of the total number of eggs removed at the time of candling as infertile, contained a dead germ of early development.

For some years observations have been made on the amount of sunshine available and its influence on hatchability.

The following table gives the number of hours of sunshine for the winter and summer hatching seasons.

From the above table it will be noticed that the month of July has three times as much sunshine as that for the month of February. There is also a monthly increase in the amount of sunshine from February until July. April has less than two hundred hours of sunshine, while May exceeds this amount by forty-six hours, hence the division into the two periods.

TABLE IV.

Showing the influence of the amount and quality of sunshine on the percentage hatchability. Per cent. Hatchability.

Ration	February	March	April	May	June	July
Milk	56·3	56·1	59	71·7	72·8	74·8
Beef Scrap	51·2	47·4	44·6	55	68·6	63·6
Tankage	10·2	21·7	29	34·9	48·4	55

Discussion.—The beneficial influence of the amount and quality of sunshine is clearly shown in Table IV. With over two hundred hours of sunshine the hatch is increased 12·7 per cent., 10·4 per cent. and 5·9 per cent. for Milk, Beef Scrap and Tankage. For all three rations already referred to, the hatching quality of the eggs gathered in May, June and July has been greatly improved over that for those of February, March and April.

The lack of sunshine during the months of February, March and April may be substituted for by such well known substitutes as Cod Liver Oil and Ultra Violet Light.

The following tables contain a summary of three years' results from several rations differing largely in the kind of protein used. In each table the results are given for a single protein supplement with and without Cod Liver Oil and also with Milk and Code Liver Oil added.

TABLE V.

Beef Scrap. Per cent. Hatchability.

Ration	Feb.	Mar.	Apl.	May	June	July	*Egg production	Lbs. feed required to produce dozen eggs	Average amount of feed consumed per bird
Beef Scrap . .	51·2	47·4	44·6	55	68·6	63·6	138·4	7·05	80·9
Beef, C.L.O. . .	69·2	67·4	59·9	71·9	70·6	72	164·2	5·95	77·5
Milk, Beef, C.L.O. .	76·9	75·2	60	59·6	66·5	74·5	165·6	5·87	81

* Eleven months only.

Discussion.—A combination of Milk, Beef Scrap and Cod Liver Oil is a more satisfactory ration than either Beef Scrap or Beef Scrap and Cod Liver Oil. When Milk and Cod Liver Oil were added to Beef Scrap the egg production is increased thirty-seven eggs per hen, the hatching power of the egg was much higher for the winter months and over one pound of feed was saved for every dozen of eggs laid. The beneficial influence of Cod Liver Oil when added to Beef Scrap is shown by the increase in the number of eggs produced pounds of feed required to produce one dozen eggs and the hatching power of the eggs for all months but more especially for those of the winter season. It is interesting to note that after two hundred hours of sunshine are available, the Beef Scrap pen produced a much higher hatching quality egg. A combination of protein supplements with Cod Liver Oil gave more satisfactory results than a single protein supplement with Cod Liver Oil.

TABLE VI.

Fish Scrap. Per cent. Hatchability.

Ration	Feb.	Mar.	Apl.	May	June	July	* Egg production	Lbs. feed required to produce dozen eggs	Average amount of feed consumed per bird
Fish	57·4	59·3	53	56·6	69·4	71·8	165·4	6·18	85·1
Fish, C.L.O. . .	64·3	60·2	50·3	63·6	66·4	67·5	177·8	5·64	83·6
Fish, Milk, C.L.O. .	79·2	74	58·8	63·3	67·9	67·9	166·6	5·91	82

* Eleven months only.

Discussion.—When Cod Liver Oil is added to Fish Scrap the egg production is increased one dozen eggs per hen for eleven months and it required less feed to produce a dozen eggs. Apparently the vitamin content has some influence on the egg production. In hatchability Cod Liver Oil does not improve the hatch for February, March and April when added to Fish to the same extent that it does when added to Milk or Beef Scrap. With Milk and Cod Liver Oil added to the Fish Scrap the hatch is greatly improved for February and March and somewhat higher for April. The egg production was eleven eggs less per hen where Milk was added to the Fish and Cod Liver Oil and it required slightly more feed to produce one dozen eggs.

While the egg production was down eleven eggs on the average for Milk, Fish and Cod Liver Oil as compared with Fish and Cod Liver Oil, the hatching power of the eggs was very much in favour of a combination ration.

TABLE VII.

Tankage. Per cent. Hatchability.

Ration	Feb.	Mar.	Apl.	May	June	July	* Egg production	Lbs. feed required to produce dozen eggs	Average amount of feed consumed per bird
Tankage . . .	10·2	21·7	29	34·9	48·4	55	126·6	7·44	78·5
Tank., C.L.O. . .	27·9	41·2	28·7	39·4	57·8	57·6	157·2	6·03	79·3
Tank., Milk, C.L.O. .	72	58·6	58·7	42·7	55·6	60·4	151	6·41	80·7

* Eleven months only.

Discussion.— Tankage gave a low egg production, eggs of poor hatching power and it required over thirty per cent. more feed to produce a dozen eggs than where Fish Scrap was used. Cod Liver Oil added to Tankage increased egg production thirty-one eggs per hen with almost one and one-half pounds of feed less required to produce one dozen eggs. The hatching quality of the eggs was improved for all months but still unsatisfactory. A combination of Milk and Cod Liver Oil with Tankage gave a fair hatch, but does not compare with the results from the other combination rations studied. Not only did Cod Liver Oil improve the hatching power of the eggs when added to Tankage but it also increased the egg production materially.

TABLE VIII.

Milk. Per cent. Hatchability.

Ration	February	March	April.	May	June	July	* Egg production	Lbs. feed required to produce dozen eggs	Average amount of feed consumed per bird
10 per cent. Milk	56·3	56·1	59	71·7	72·8	74·8	143·6	7·05	84·4
10 per cent. Milk, C. L. O.	73·4	69·9	60·6	54·8	64·1	65·1	153·5	6·48	82·8
† 37 per cent. Milk, C. L. O.	75·8	75·7	65·8	74·1	80	73·3	153·7	6·07	77·8
‡ 10 per cent. Milk, Irrad.	74·1	77·2	71·7	74	79·5	77·1	139·8	7·01	81·7

* Eleven months only.
† Two year results.
‡ Birds handled every day except Sunday.

Discussion. With the addition of Cod Liver Oil to Milk the number of eggs produced was increased, hatchability was improved considerably for the winter months and less feed was required to produce a dozen eggs. Again it may be seen that the amount of Vitamin supplied has not only influenced the hatching power of the eggs but also the egg production. By increasing the amount of Milk in the diet to 37 per cent. there was no increase in the egg production although a little feed was saved. However, the hatching quality was higher for all months. Irradiation from a Mercury Quartz Lamp would appear to be more efficient in supplying the necessary Vitamin D than Cod Liver Oil when the results are compared. The egg production is low for this pen but in view of the fact that the birds were handled every day, except Sunday, and carried in a crate to the top floor of the Poultry

Building, introduces a point of difference in comparing this pen with the other pens. It would seem that when Milk is fed at the same lavel as Beef Scrap, Fish Scrap or Tankage, there is a possible wastage of this material.

TABLE IX.

A combination of proteins. Per cent. Hatchability.

Ration	February	March	April	May	June	July	*Egg production	Lbs. feed required to produce dozen eggs	Average amount of feed consumed per bird
Milk, Fish	58·2	49·1	30·9	42·6	64·5	68·1	141·4	6·78	79·9
Milk, Fish, C. L. O.	79·2	74	58·8	63·3	67·9	67·4	166·6	5·91	82
Milk, Beef, C. L. O.	76·9	75·2	60	59·6	66·5	74·5	165·6	5·87	81
Milk, Tank., C. L. O.	72	58·6	58·7	42·7	55·6	60·4	151	6·41	80·7

* Eleven months only.

Discussion.—There are many of the opinion that heavy egg production tends to decrease the hatching power of eggs. This does not seem to be the case when the results for the two diets—Milk, Fish Scrap, Cod Liver Oil, and Milk, Beef Scrap, Cod Liver Oil are considered. The average production for eleven months was 165 and 166 respectively while the per cent. hatchability would average over seventy per cent. for the February, March and April period. When Tankage is used in place of either Fish Scrap or Beef Scrap, the egg production is down fourteen eggs per bird, more feed is required to produce a dozen eggs and the hatching power of the eggs is decreased considerably. Twenty-five eggs more per hen are recorded when Cod Liver oil is added to Milk and Fish, almost one pound of feed is saved every time twelve eggs are produced and the hatching quality of the eggs increased very greatly for the more important months to the hatcheryman.

A study of the three years summary shown in Table X seems to justify the following conclusions :—

1. Comparing the feeding value, from the standpoint of egg production, Fish Meal, Powdered Buttermilk, Beef Scrap and Tankage, rank in the order named.

2. The addition of Cod Liver Oil to a single protein supplement increased the egg production with all rations tested but much more with Beef and Tankage than with Milk and Fish.

3. A combination of Fish Scrap and Milk failed to increase either the hatching power of the eggs or the number of eggs produced.

4. Cod liver Oil added to a combination of Milk and Fish Scrap; Milk and Beef Scrap; Milk and Tankage; did increase both the hatching power of the eggs set and the number of eggs produced.

5. It would appear that Tankage fed to poultry alone or in combination is not the most desirable kind of ration.

6. With a grain ration such as used plus alfalfa meal, the addition of direct sunshine or sunshine substitutes (a good grade of Cod Liver Oil or Ultra Violet Light) is the most important factor in producing good hatching eggs for the rations tested.

7. Vitamin D appears to be a very important factor in hatchability. Birds housed in these feeding trials did not get the necessary amount until there was at least two hundred hours of sunshine per month.

8. Milk in combination with Beef Scrap or Fish Scrap together with Cod Liver Oil appears to be the most satisfactory feed used in these trials, where hatching power of eggs, number of eggs produced and pounds of feed required to produce one dozen eggs are considered.

TABLE X.

Summary of three years results. Per cent. Hatchability.

Ration	February	March	April	May	June	July	Egg production, 11 months	Lbs. feed to produce one dozen eggs	Average feed consumed per bird	Total eggs set for three years
Milk Beef, C. L. O.	76·9	75·2	60	59·6	66·5	71·5	165·6	5·87	81	5851
Milk, Fish, C. L. O.	79·2	74	58·8	63·3	67·9	67·1	166·6	5·91	82	5730
Milk, Irradiation	74·1	77·2	71·7	74	79·5	77·1	139·8	7·01	81·7	4732
10 per cent Milk, C. L. O.	73·1	69·9	60·6	54·8	64·1	65·4	153·5	6·48	82·8	5430
*37 per cent Milk, C. L. O.	75·8	75·7	65·8	74·1	80	73·3	153·7	6·07	77·8	3682
Milk, Tank., C. L. O.	72	58·6	58·7	42·7	55·6	60·4	151	6·41	80·7	5256
Beef, C. L. O.	69·2	67·4	59·9	71·9	70·6	72	164·2	5·95	81·3	6103
Fish, C. L. O.	64·3	60·2	50·3	63·6	66·4	67·5	177·8	5·64	83·6	6575
Fish	57·4	59·3	53	56·6	69·4	71·8	165·4	6·18	85·1	5958
Milk	56·3	56·1	59	71·7	72·8	74·8	143·6	7·05	84·4	4985
Beef Scrap	51·2	47·4	41·6	55	68·6	63·6	138·4	7·01	80·9	4683
Milk, Fish Scrap	58·2	49·1	30·9	42·6	64·5	68·1	141·4	6·78	79·9	4630
Tankage, C. L. O.	27·9	41·2	28·7	39·4	57·8	57·6	157·2	6·05	79·3	5890
Tankage	10·2	21·7	29	34·9	48·4	55	126·6	7·44	78·5	4523

* Two years.

LETHAL FACTORS AND LIVE-STOCK BREEDING

A REVIEW.

[Reprinted from the *Quarterly Bulletin*, Vol. 2, No. 3, July 1931, of the Imperial Bureau of Animal Genetics, King's Buildings, University of Edinburgh, Scotland.]

As a craft and as a science, live-stock breeding may be said to consist essentially of the maintenance of progress so far and the furtherance of the breed towards an ideal type of the animal bred; and this statement is not nullified by the fact that the ideal type may not be universally recognised, that it may change from time to time or that it may be dictated by fancy or economic requirements. To supplement this statement we may say also that the live-stock breeder has constantly in mind the exclusion from his strains of defects which would vitiate his attempts at positive improvement, the defects which are often referred to in the nebulous phrase, "the ill effects of inbreeding". It is not necessary to emphasise that inbreeding is not in itself detrimental, but we would draw attention to a few out of the wide range of troubles which can be broadly classed as hereditary defects. These may vary in expression from the death of the fertilised ovum to some small defect which may prevent the individual or the strain from competing on the same terms in life as its fellows. It is impossible to draw definite lines of demarcation in the classification of such defects, but under the broad heading of lethal and sub-lethal factors may be grouped those hereditary defects which result in the death of the individual sometime between conception and a few days after birth.

The term lethal factor, used in the genetical sense, refers to the inheritance by an individual, from both parents, of a character which prevents the full and normal development of the individual and results in the organism's death during the early stages of embroynic development or at birth. The characters which lethal genes impose upon their exhibitors are various; they have been noted in most species of domesticated stock and it is probable that they are far more common than is generally suspected.

There are certain points in the genetics of lethal factors which are worthy of particular explanation. For all practical purposes, lethal genes are recessive in their lethal effect, *i.e.*, it is the individual inheriting the factor in the duplex or homozygous condition that dies. The heterozygote can live and perpetuate its species. A dominant lethal gene would of course be self-eliminating. However, the recessive lethal gene may express some dominance of the character associated

with it, or of a linked character, in the heterozygote, or it may, on the other hand, exhibit nothing in the heterozygote which would enable its identification in such an individual. Let us consider some examples, such as the lethal factors operating in the Dexter breed of cattle, hooded canaries and Swedish Holstein-Friesian cattle, the character of each of which will be described later.

The homozygous Dexter is the bulldog calf, yet the heterozygote exhibits the same character in a much slighter but still very obvious degree, in that the beast the typical Dexter, is short-legged and generally thick-set. The progeny of Dexters not carrying the factor at all, have normal length of leg and are indistinguishable from Kerry cattle. Thus, it is mere human whim which perpetuates this condition, for as the heterozygotes are readily detected, they could be easily eliminated from the breeding stocks. Naturally, such elimination would mean the end of Dexter cattle as a breed, but that would be no great loss, for the superior beef qualities of the Dexter type do not compensate economically for the loss of 25 per cent. of the calves and the futher disposal of 25 per cent. Kerry type calves. Similarly in hooded canaries, the homozygous hooded is nonviable, yet the individuals carrying the lethal factor recessively are recognisable in that they are hooded, and the non-hooded progeny do not inherit the factor. Here, we are not entitled to assume that the death of the homozygous embryo is due to its inherent duplex hood, but that the factor for hooded is one which is intimately *linked* with the lethal gene operating on the homozygotes. It is, perhaps, a "glimpse of the obvious" to say that it is the fancier's wish for hooded canaries which perpetuates the operation of the lethal factor.

Then there is the classic example of the yellow mouse of which variety only heterozygotes have been bred. At one time it was considered that yellow colour was merely linked with the lethal factor operating on the homozygotes, but recent thought and experimentation tend to actually identify the yellow factor with the lethal, because the yellow coat colour appears to be chemically concerned with the peculiar fat metabolism of the yellow mouse.

We have a very different position in the example of the lethal gene "hairless" in Swedish Holstein-Friesian cattle. The factor is purely recessive, there are no linked factors to display an identifying character and the heterozygote is indistinguishable from normal animals not carrying the factor. As will be explained later, it is this type of lethal factor which can work considerable havoc in a breed or strain, as large numbers of heterozygotes may be bred and distributed without detection.

The genetics of these recessive and semi-recessive lethal factors may be most easily understood by reference to the yellow mice, studied so completely by Cuenot

(1905-08) and Castle (1910), and the later American investigators Kirkham (1917-19), Ibsen and Steigleder (1917). It has been already implied that pure strain of yellow mice cannot be bred. Individuals of another colour appear in the litters to the extent of one-third of the number, on the average.

It was noticeable too that yellow mice mated *inter se* produced litters that were on an average one quarter fewer than when yellow mice were mated with mice of other colours. The conclusion of Cuenot was that the yellow mice which inherited a constitution for yellow in double quantities (*i.e.*, the homozygotes) perished during the embryonic stage. The younger Americans dissected female yellow mice pregnant by yellow males and found dead embryos present to the extent of 25 per cent. of the total foetuses.

Yellow × Non-Yellow	50 per cent. yellow (heterozygous and viable). 50 per cent. non-yellow (viable).
Yellow × Yellow	25 per cent. yellow (homozygous, dying as embryos). 50 per cent yellow (heterozygous and viable). 25 per cent. non-yellow (homozygous and viable).

If the "carrier" of a lethal gene, such as bulldog or "hairless", is substituted for the yellow mouse in the above equations, the incidence of expression of such defects is obvious.

We will consider in more detail some of the lethal factors noticed in live-stock breeding.

The lethal factor best known to British breeders is that which results in the "bulldog" calf of the Dexter breed of cattle. Approximately 25 per cent. of Dexter calves are born dead and are monstrous in appearance, their heads, limbs and vertebral columns being much foreshortened. Frequently these calves are aborted at the sixth month, but are carried sometimes until the eighth month, when considerable difficulty is experienced in parturition. A detailed description of the condition (*achondroplasia congenita*) has been given by Crew (1924). A similar lethal factor operating in certain strains of the Scandinavian Telemark breed has been studied by Wriedt and Mohr (1925-26). In this breed the calves are carried to full term, and are often born alive, but they die within two or three days from respiratory paralysis as an immediate cause. Malformed calves of seemingly analogous type have been found in German Holstein-Friesians and described by Weinkopff (1927), and it is believed that an Ayrashire herd in Sweden also carries this lethal factor. In addition, Adametz has studied the condition in some detail.

Hadley and Warwick (1927) discovered a lethal factor in herds of Friesian cattle in America. The character of this factor gives the calf the appearance of being devoid of skin and hair in certain areas of the body, particularly the muzzle and feet (*epitheliogenesis imperfecta neonatorum bovis*). Death occurs within a few days of birth. Studies of the pedigrees of the parents of these calves, showed that they all traced to the same foundation stock imported from Holland in 1871. Similarly defective calves also occur in Holland in herds carrying the same blood lines.

Three other lethal factors of cattle have been described in detail by Wriedt and Mohr (1928 and 1930). One results in the birth of hairless calves, due directly to a marked delay in the embryological development of the skin. Another is exhibited in the birth of calves whose extremities—the fore part of the face and the limbs—are only rudimentarily present (*akroteriasis congenita*). This lethal factor is present in strains of Swedish Holstein-Friesian cattle and it is curious to find that another lethal found in a Norwegian mountain breed is the reciprocal of *akroteriasis congenita* in that the vertebral column and thorax are extremely foreshortened ("short spine") whilst the head and limbs are normal. The bones abnormal in the one type are normal in the other.

Loje (1930) records two examples of hereditary defects in Red Danish cattle, one having a definitely lethal effect. Cows giving birth to affected calves carried them full time, but owing to the large size of the calves birth was difficult. Large quantities of amniotic fluid were passed. The calves were stillborn, death having occurred about the eighth or ninth month of gestation. They were covered with short fine hair and were rigid and hard to the touch. The head and neck were short, but the limbs were of normal length although rigid and distorted. No abnormalities were discovered in the internal organs. On investigating the pedigree of the abnormal calves, Loje found that the dams were all half-sisters sired by one bull which occurred also in the sires' pedigree and who apparently carried the lethal factor responsible for the defect.

The second case described by Loje is that of a semi-lethal gene causing lameness. The calves are born at full term and fully developed but were unable to stand owing to lameness of the hind legs. The defect appeared in three different herds of Red Danes and only when animals of a certain ancestry were mated.

Yamane (1925 and 1927) has described a lethal factor present in horses in Japan. Post-mortem examination of the foals affected, which died in two to four days, showed that the large intestine was completely cut off in the region of its pelvic fixture (*atresia coli*). The immediate cause of death naturally, was that the alimentary system could not function. This lethal was spread in Japan by a Percheron stallion imported from the United States about forty years ago, but the

same condition has appeared in Germany in the offspring of an East-Friesian stallion.

During the eighteenth century, the Royal family of Denmark owned a stud of black-eyed white horses. When these white mares were mated to white stallions, it was ultimately found impossible to produce foals. These mares, thirteen in number, mated to a grey stallion produced ten foals. In this instance a lethal factor acting at an early stage of embryonic development gave the impression that the mares had not even conceived to the white stallion. This case is typical of the kind of lethal factor which may be operating in many of our highly bred strains of live stock, where fertility is found to be very low. The apparent effct is that of sterility.

Roberts (1926 and 1929) has demonstrated the inheritance of a lethal factor in Welsh Mountain sheep. The affected lambs, which die at birth or soon after, are found to have limbs rigidly fixed in various positions only a slight degree of movement being possible at the joints affected, without breakage of the limb. Miller, in describing the condition, says that the limb muscles causing the rigidity are represented by masses of fibrous tissue containing less than 50 per cent. of muscle fibres. The bones of the limbs are normal. This lethal factor in lambs tends towards its own elimination as there is considerable mortality among the ewes giving birth to these lambs.

In Norway, Wriedt and Mohr studied a recessive factor in the sheep which produced many abnormalities, *e. g.*, earlessness, cleft palate, shortened lower jaw and in many cases a trichotomy of the hoof. The action of this factor seems to be variable, but in all probability it is a sub-lethal.

In swine there is evidence of the operation of lethal factors when variations in litter size are considered. Inbred strains of pigs tend to give small litters when mated within the strain. It might be said that the waning popularity of the Berkshire breed is due to the prevalence of small litters, yet a Berkshire sow mated to a boar of another breed, say a Large White, will give, probably a large viable litter. Corner (1923), Hammond (1921), Parkes (1925) and Crew (1925) have given their attention to litter size in swine, and in post-mortem examinations of pregnant sows found many examples of atrophied foetuses and circumstantial evidence of re-absorbed embryos. Crew noted particularly that the prenatal mortality in swine appeared to act selectively upon the digametic sex, the males. Serotal and umbilical hernia in pigs appear to be hereditary defects acting in a semi-lethal manner.

Mohr (1929) mentions the existence of a typical recessive sub-lethal in the pig, though a full paper has not yet been published. The factor, in the homozygous

condition, causes a complete paralysis of the pelvic limbs. The figures of segregation are in agreement with expectation for a single recessive.

There is accumulating considerable evidence to demonstrate the presence of lethal factors in poultry. Crew (1924) and Landauer and Dunn (1930) have shown that it is not possible to breed pure strains of "dumpy" fowls as the individuals inheriting these characters from both parents in a pure state perish in the egg before hatching. The dumpy fowl is analogous to the Dexter breed of cattle, in that it is an achondroplasiac form. Hutt (1930), and Landauer and Dunn (1930) have shown that whilst homozygous "frizzle" fowls can be bred, they are much less viable than normals or heterozygotes and few reach sexual maturity.

Dunn (1923) detected a strictly lethal gene in the White Wyandotte fowl owing to its linkage with a recessive white factor in that breed.

Of more immediate application to economic poultry husbandry are the results of some of the American workers who have investigated the all-important subject of hatchability, which, of course, is intimately bound up with the possibilities of the presence of lethal factors.

Jull (1929-30) has interesting results to offer from analyses of the records of the breeding flocks of Barred Plymouth Rocks, Rhode Island Reds and White Leghorns at the United States Animal Husbandry Farm.

One of his studies was concerned with hatchability in relation to the consanguinity of the breeding stock, following one of his previous statements, based on an extensive survey of the literature, that "it may be concluded fairly definitely that the problem of improving hatchability is largely a problem of breeding". Both full-brother-and-sister and half-brother-and-sister matings were made and such matings tended to decrease hatchability by increasing both the percentages of embryos dying between the 1-17th days and 18-21st days of incubation, but the embryonic mortality during the second period was affected to a greater extent. The hatchability results were affected most largely in the first year of inbreeding rather than in successive years, though a general decline was apparent each year that such close inbreeding was continued.

In a further investigation, by Jull, hatchability was studied in relation to coefficients of inbreeding of the breeding stock. As the previous study showed, hatchability decreased as the coefficients of inbreeding increased. The greatest relative decrease in hatchability appeared to occur between a coefficient of inbreeding of 0 and 12·5. The same coefficients, regardless of the year in which they were produced, did not give significant differences in hatchability results. Continuous full-brother-and-sister matings were more detrimental to hatchability than full-brother-and-sister matings alternated with half-brother-and-sister matings.

Again, the effect of inter-crossing inbred strains of chickens on fertility and hatchability was observed. It was shown, in general, that the hatchability percentage increased in the inter-crossed inbred strains above that observed in the inbred matings.

Jull's work on hatchability brings us to a consideration of the studies in embryonic mortality conducted by Hutt and Greenwood (1920) at Edinburgh. Nearly 12,000 eggs which had failed to hatch were examined, among which were over 5,000 embryos which died after the eighteenth day. Four major malpositions of the embryo were found and whilst one of these in which the head is buried between the legs definitely prevents hatching, the other three result fatally by reason of their preventing pulmonary respiration in the embryo, as well as by mechanical hinderance. The suggestion is made that some of the abnormal positions result from an incorrect orientation of the embryo established early in cleavage. From a consideration of the embryos examined from eggs of the Departmental flock, it seemed that the tendency to produce embryos in abnormal positions is a hereditary one.

Another cause of embryonic mortality studied by Hutt and Greenwood is chondrodystrophy, which, without going into detailed description, may be looked upon as a comparable condition to that of the bulldog calf in the Dexter breed of cattle, although not so directly similar as the " dumpy " defect in fowls already mentioned. The affected embryos are typically achondroplasiac. Dunn (1927) had previously studied chondrodystrophy in the Connecticut Experiment Station flock but its occurrence was not nearly so frequent as in the Edinburgh flock. The theory is advanced that, whilst a hereditary physiological abnormality in the dam would appear to be involved, the condition is most frequently exhibited under sunshine starvation of the breeding stock. The incidence of chondrodystrophy was found to be greatest in January and February and declined steadily to an almost complete absence in June.

When it is remembered that loss to poultry keepers by mortality among embryos during incubation is probably second only to that incurred by disease, the importance of the foregoing studies on hatchability and embryonic mortality can be realised.

Elsewhere in this issue appears a short paper from Mr. C. S. M. Hopkirk of New Zealand, describing a hæmorrhagic diathesis in certain strains of White Leghorn hens which would appear to be hereditarily transmitted. As far as we know this is the first notice of such a condition, and it provides an excellent example of how close observation, followed up by a critical *ad hoc* breeding experiment, may result in the early elimination of the defect. The fact that the defect is not of economic

importance in its present rate of incidence is obviously not sufficient reason to allow the condition to run unchecked through the flocks.

The late Christian Wriedt accomplished an immense amount of work in the identification of lethal factors. In addition to those in cattle already mentioned as being due in part to his work, he found that in doves there is a colour modifier which reduces red to yellow and black to grey. Yellow and grey individuals seem weaker than red and black ones, and if the gene responsible for this reduced vitality occurs in conjunction with a certain gene for speckling on the feathers, then the young are practically devoid of down and mortality is very high.

He found also, that the Scandinavian Dunkerhund carries a semi-lethal or defect-producing factor. This breed is usually grey with black spots and small white markings. On mating two such individuals, half the progeny resembles the parents in colour, whilst one quarter are brown or black and one quarter white with isolated dark spots. The last mentioned group is comprised of the homozygotes of the breed type and the individuals show greatly reduced vitality. They have usually abnormally small eyes and oblique pupils, resulting in blindness. In some instances glaucoma has been observed and deafness is frequent.

Kislovsky (1928) has described a hereditary defect in rabbits characterised by hairlessness and defects of the teeth. The young affected do not grow as rapidly as their litter mates and they die before reaching the age of one month. This defect must, therefore, be classed as a sub-lethal, although, as Kislovsky implies, death is due probably to the mechanical inefficiency of the teeth, rather than as a direct result of the physiological condition. Hammond, also, has found a hereditary hairless condition in rabbits, but the effects are not so pronounced as in Kislovsky's examples.

Among cats, as studied by Bamber and Jones, fœtal mortality among white females is very high and it is assumed that the factor responsible for this high death rate is linked with, if not identical with, the factor for white colour, which apparently has a lethal effect in some cases, even when in the simplex condition.

We come now to a general consideration of the importance of the existence of lethal factors in the economy of live stock breeding. Due to the show system, certain breeders and particular animals of their herds have arrived at considerable notoriety during the last eighty or a hundred years. For instance, it would be difficult in these days to find a pedigree Shorthorn beast that did not trace back to Cruikshank's great bull Champion of England which was in his prime only sixty years ago. Similarly in the carefully kept records of the German

Shepherd Dog it would be hardly possible to find one of these dogs which did not carry the blood of the great dog Horand von Grafrath which was in service in 1900. Thus, where a whole breed carries the blood of one or two outstanding animals, undesirable recessive factors such as lethals are apt to crop up continuously, even though the animals homozygous for the factor are eliminated automatically or by selection. In the eradication of a defect, or at least its nullification, heterozygotes must never be mated *inter se*. Unfortunately, the only test for the detection of the heterozygote sire, in the case of purely recessive lethals, is by breeding him to a sufficient number of his offspring. Frequently a sire heterozygous for an undesirable factor, *e.g.*, a lethal, may by the excellence of his parents or his success in the show ring be used on a considerable number of heterozygous females, resulting in the appearance of 25 per cent. of the young exhibiting the undesirable character.

In Northern Europe, to a greater extent than in Britain, bulls are kept to an advanced age and many are tested on twenty of their own daughters or to nine or ten known heterozygous cows before they are accepted as being free from a recessive lethal gene and used as breeders of breeding bulls. This means that a bull has reached the age of about seven years before he has given twenty calves with his own daughters. To refrain from using a bull for breeding bulls until he is seven years old, renders live-stock improvement an even slower undertaking than it is at present, but if lethal factors are present in a strain or throughout a breed, such breeding tests are extremely valuable. In addition to ensuring the selection of bulls not carrying the lethal factor, considerable data and records concerning the inheritance of other factors such as that for high milk yield may be collected. The economic result of allowing a lethal to run unchecked in a herd or breed has to be considered.

As the calf is the main product in beef breeds, the loss of say one calf born dead in eight is a very serious matter. Mohr and Wriedt (1928) have encountered herds losing calves in this proportion where a lethal factor is operating. In milk-producing animals the calf is not the main objective, but from a breeding point of view it is most undesirable to lose the *chance* of rearing all the heifer calves born. The Danish statistics for 1923 showed the birth of 86 calves per 100 cows. Say half of these are heifers, some are lost in early life, and Fredriksen (1924) suggests that 38 viable heifers per 100 cows per year is a fair output. Usually, round about 50 per cent. of cows in a herd may be considered suitable for the task of replacing heifers into the herd, which means that about 20 heifer calves per 100 are available at first calving to make the replacements in the herd. This number gives a very small margin to keep up the full herd of 100, which means that further depletion of heifer calves due to the

operation of a lethal factor may have more far-reaching results than the initial loss of the calf's carcase may indicate. Elsewhere in this issue of the *bulletin* is abstracted a paper bearing out still further the difficulties of herd replacement. Moreover, psychological consequences cannot be ignored. The possibility of purchasing and breeding expensive animals giving rise to monstrous calves and still-births is in itself apt to cause apprehension and timidity in a buyer, resulting in lower than normal prices being paid.

In swine, the large number of offspring per litter allows a smaller number than twenty daughter sows to be tested to him. If a lethal is present in a herd of pigs a boar should be given six of his own daughters and if the defect does not appear in any of the offspring he may be accepted as being free of the lethal.

In sheep, the requirements would be similar to those suggested for cattle, which would mean a ram being three years old before being used for breeding breeders.

These preventive measures involve considerable difficulties, but in meat-producing animals, the consequences of a recessive lethal gene present in the stock are sufficiently serious to justify the adoption of such measures. Breeders, instead of hiding the presence of a recessive lethal in their stock, should keep careful records sufficient to assist in the detection of the carriers and their ultimate elimination. [F. D.]

ABSTRACTS

The Importance of the Shape of Plots in Field Experiments. BASIL G. CHRISTIDIS. *J. Agri. Sci.* 21, 14-37.

1. In agricultural experiments it seems that significant results cannot be secured by only using appropriate statistical methods; uniformity amongst the individual plots is more essential than anything else.

2. Some theoretical considerations suggest that the shape of the plots constitutes an important means of controlling soil heterogeneity. In accordance with these: (*a*) in no case can square plots be more uniform than long and narrow ones, (*b*) the smaller the value w/l the more uniform the experimental plots, and (c) since uniformity depends (apart from w/l) on the value of the angle a, in some exceptional cases (soil fertility varying gradually and evenly, and angle a approaching 90°) the advantage of the long plots may be less than would be anticipated. This, however, is most unlikely on account of the complexity of the variation in soil conditions and the possibility of easily avoiding such a critical value of the angle a.

3. In order to test the validity of the assumption made regarding the effect of the shape of the plots, the numerical data of several uniformity trials have been considered. A close agreement was found between expectation and actual results, in the great majority of cases the evidence being remarkably significant in favour of the long plots. In only three cases were the results inconclusive, this apparently being accounted for by the way in which the original plots were formed, causing an inequality in area amongst them.

4. In the light of these investigations, in order to reduce the effect of soil heterogeneity, the plots used should be as long and narrow as possible. This, of course, within the limits set by different practical considerations, amongst which convenience, competition (when acting), and the accurate measurement of the width appear to be the most important.—*Author's summary.* [Reprinted from the *Herbage Abstarcts*, Vol. I, No. 1, June 1931 issued by the Imperial Bureau of Plant Genetics (Herbage Plants).]

Some Studies in Respiration and other Metabolic Activities in Berries of the Grape Vine (*Vitis vinifera*, Linn.). JAI CHAND LUTHRA, AND INDAR SINGH CHIMA. (*Ind. J. Agric. Science* 1, 695-714.)

Although considerable attention is being paid to the improvement of the grape vine in India, little is known about the physiological activities and chemical composition of its fruits. In this paper an account is given of a preliminary study of the subject from these points of view. The studies have been made on the berries of *Jaishi* and *Tur* varieties. The results show that the berries respired actively during the early stages of growth and the rate slowed down as berries grew old.

The rate of respiration in bunches attached to the plant was almost identical with those removed from the plant.

CHEMICAL COMPOSITION.

No starch was found either in the young or in fully developed berries. Reducing sugar form the greater part of the grapes and their amount increases as ripening proceeds. In 2 days' old grapes the amount of sugars was about 1 per cent. and in two months' the amount rose to 88 per cent.

Malic acid and tartaric acid are the chief organic acids found in grapes. The quantity of these acids increases for about 5 weeks. The maximum estimated was 36 per cent. Afterwards acidity begins to decline rapidly and about three per cent. only is left in fully matured berries. [Authors' abstract].

Studies in Sorghum I. Anthesis and Pollination. G. N. RANGASWAMI AYYANGAR AND V. PANDURANGA RAO. (*Ind. J. Agric. Science* **1**, 445-454).

This article records observations made on Sorghum for two years in both summer and main season at Coimbatore.

The "flag", which marks the beginning of the reproductive phase, takes six days to emerge. The "boot" and the panicle come out completely in nine and five days respectively. Longer duration varieties take longer time. The stalk takes five days to push the panicle aloft.

The topmost flowers in each branch open first and flowering spreads down gradually. Among the branches it proceeds from top to bottom. The panicle takes eight days to finish flowering, the maximum number of flowers opening between the third and sixth days. The period of anthesis is between midnight and 10 A.M. The flowers keep open for forty-five minutes generally.

Anthers emerge in a column enclosing the stigmas. Dehiscence of anthers is simultaneous with the opening of glumes. Stigmas remain outside clipped between closed glumes.

Pedicelled male flowers are generally abortive. Only the pairs attached to the end hermaphrodites bear anthers. In loose panicled types no antheriferous males are found. Male flowers open at the close of the main wave of the anthesis of hermaphrodites. The glumes of these remain open for a very long time. [Authors' abstract.]

The Inheritance of Characters in *Ragi, Eleusine Coracana* (Gaertn), Part I. Purple Pigmentation. G. N. RANGASWAMI AYYANGAR AND P. KRISHNA RAO. (*Ind. J. Agric. Science* **1**, 435-444).

Varieties of *ragi* are either Purple Pigmented or Green-throughout. The Pigment is of the anthocyanin type. The purple pigmented group as three distinct types, *viz.*, Purple, Dilute Purple, and Localised Purple. "Purple" is the commonest kind under cultivation and can be readily recognised by the presence of purple pigmentation prominently manifested in the leaves bent down by the wind, in leaf-junctions, nodes, earheads, anthers and stigmas. In the "Dilute Purple" the pigmentation is markedly reduced in the glumes, and is almost absent in the nodes, while it is similar to purple in other respects. In the "Localised Purple" the pigmentation is very much reduced and shows faintly in the glumes on the margins of the sutures after the dehiscence of the anthers, and in the stigmas. The Green-throughout is characterised by the complete absence of purple pigment.

As in other cereals Purple Pigmented plants are dominant to Green-throughouts in *ragi*. Breeding tests have shown that in the pigmented types each is a single factor advance over the next lower one, and have also revealed the possibility of classifying the Green-throughouts into types of various kinds of Purple Pigment producing potentials. [Authors' abstract.]

The Inheritance of Characters in *Ragi*, *Eleusine Coracana* (Gaertn), Part II. Grain Colour Factors and their Relation to Plant Purple Pigmentation. G. N. RANGASWAMI AYYANGAR, P. KRISHNA RAO, AND U. ACHYUTHA WARIAR. (*Ind. J. Agri. Science*, **1**, 538-553.)

Ragi has a characteristic brown colour on the grain. This brown is designated *Ragi* Brown. The pigment is confined to the outer layer of the seed-coat. This *Ragi* Brown is produced by two factors B_1 and B_2 either alone or together. This brown colour of the grain is in intimate genetic relationship with Plant Purple Pigmentation. Purple Pigmentation on the plant is produced by a factor S working in association with either or both of the B factors. This accounts for the absence of white grained *ragi* in purple pigmented plants. Some races of white grains carry the factor S. Crosses have been made between white grained plants containing the S factor with brown grained Green-throughouts, and the resulting F_1 plants were purple pigmented and brown grained. These crosses behaved as expected in later generations.

A factor D that deepens the effect of the B factors behaves as a simple dominant. This is independent of the factors concerned in the production of Plant Purple Pigmentation and is not in selective association with either of the B factors. [Authors' abstract.]

The Inheritance of Characters in *Ragi*, *Eleusine Coracana* (Gaertn), Part III. Sterility. G. N. RANGASWAMI AYYANGAR AND N. KRISHNASWAMY. (*Ind. J. Agri. Science*, **1**, 554-563.)

Chronic sterility, short of complete sterility is occasionally met with in *ragi*. It manifests itself in an almost complete failure to set seed and gives the earheads a blighted look. Sterile plants grow vigorously, flower late and put forth numerous heads. The anthers lack the free and quick protrusion which gives the healthy earheads that fullness characteristic of the blooming period. The stigmas are healthy and receptive.

The cause of this sterility is two-fold, (1) a Non-dehiscence of anthers and (2) an Agglutination of pollen. In the first type of sterility the anthers are of the same shape and size as healthy ones. They are full of viable pollen grains, but the anther sacs do not dehisce and liberate their contents. In the second type of sterility a disintegrated mass of agglutinated pollen devoid of contents is produced. In both the types, however, a few stray grains develop and help to keep the race going. Normal dehiscence occurs with the presence of factor X. Free pollen is produced by factor Y. Both the factors X and Y behave as simple dominants to their absence which results in sterility. The X and Y factors are independent of the factors responsible for Plant Purple Pigmentation. [Authors' abstract.]

The Inheritance of Characters in *Ragi*, *Eleusine Coracana* (Gaertn), Part IV. Depth of Green in the Pericarp. G. N. RANGASWAMI AYYANGAR, P. KRISHNA RAO and N. KRISHNASWAMI. (*Ind. J. Agri. Science*, 1. 564-569.)

Young growing grains of *ragi* have generally a Green Pericarp. The green colour shows itself while the grain is still young and continues to be present even after the growing grain passes the milky stage. About a week later, it dries off into a thin loose greyish translucent and fairly persistant membrane, enclosing the mature grain.

A variant of this type has been met with. This shows itself as a distinct light Green Pericarp, which in the early stages gives a lighter tint of green even to the earhead. The Green Pericarp is associated with a dry anther mass of pale orange yellow and the light Green Pericarp, with ivory yellow.

The Green Pericarp is brought about by the presence of a factor designated C_x and is a simple dominant to the light Green Pericarp. This factor C_x is independent of the factors for Plant Purple Pigmentation and Grain Colours. [Authors' abstract.]

The Inheritance of Characters in *Ragi*, *Eleusine Coracana* (Gaertn), Part V. Albinism. G. N. RANGASWAMI AYYANGAR, and P. KRISHNA RAO. (*Ind. J. Agri. Science*, 1, 570-577.)

Albino seedlings are sometimes met with in *ragi*. These seedlings in consequence of their being completely devoid of Chlorophyll, are characterized by poor growth and slow development both of shoot and root. Many of these stop with two leaves while the greens of the same age have four. About 9 days after sowing the leaf tips of the whites begin to shrivel up and a day or two thereafter the white seedlings begin to die off.

By genetic analysis it has been established that two factors designated C_1 and C_2 either alone or together are responsible for the production of green colouring matter in the *ragi* plant. The absence of both the factors results in a white seedling.

Segregations in the ratio 15 : 1 have been obtained and this behaviour was confirmed by further generations. Pure lines for the factors C_1 and C_2 have been extracted. When these two were crossed the F_1 was green, and in the F_2 segregated into the expected 15 : 1 ratio of greens and white —thus artificially producing albinos.

These factors C_1 and C_2 are independent of the factor C_x responsible for the production of the full green colour in the young *ragi* pericarp. [Authors' abstract.]

Some Observations on the Growth of *Sesamum indicum* in Different Soil Conditions. with Special Reference to Root Development. KASHI RAM and R. MADHAVA ROW. (*Ind. J. Agri. Science*, 1, 715-717.)

The paper deals with the results of an experiment tried with two types of *Sesamum indicum* to find out which type of soil is most suitable to the crop. The types were grown in wire netting pots filled with mixtures of sand and clay in different proportions. The results showed that the sesamum crop prefers a light sandy soil for its maximum development. [Authors' abstract.]

Silage Investigations at Bangalore, II. Quality and Yield of Silage in Relation to Filling Conditions. T. S. KRISHNAN. (*Ind. J. Vet. Science and Anim. Husbandry*, 1,259-282.)

The effect of varying the condition of ensilage of *jowar* was studied. Two pits were filled rapidly and two others slowly and one of each was watered moderately. The surface losses due to rotting and similar causes were much more in the rapidly filled ones than in the others. The losses in the various pits due to chemical action, taking only the good silage, were nearly the same. Watering gave the product a better aroma.

The extensive decomposition of true protein to "amides", with the production of volatile bases and amino acids and the relationship between the last two products was a confirmation of the

previous work here. The same agreement was noticed in the case of volatile and non-volatile organic acids production as well.

Carbohydrate losses, however, were higher than in the previous experiment, but agree with the Cambridge results.

There is seen a gradually increasing concentration of the soluble substances towards the bottom layers of the pit owing to the leaching action of the drainage juice. Even silica, an insoluble substance, exhibits this movement.

It has been found that slow filling with watering, if necessary, results in the production of good silage with the least losses in the various constituents. [Author's abstract.]

Investigations into the Fluctuations of Milk Yield with the Advancement of Lactation. L. S. JOSEPH and C. N. DAVE. (*Ind. J. Vet. Science and Anim. Husband.* **1, 200-211.**)

A study of 24 years' records of the Pusa Pedigree Sahiwal herd relating to the variability of milk yield with the advancement of lactation leads to the following conclusions:--

(1) the total percentage decline in the yield is the least in the first lactation.

(2) from the second to the eighth lactation the average percentage decline in the yield remains practically constant; and

(3) on the whole, the average percentage of monthly decline works out at 7 6.

It is expected that these results will be of value to dairymen in maintaining a regular and steady supply of milk to their customers and thus over-coming the difficulties with regard to the surplus or shortage of milk. [Authors' abstract.]

Recommendations of the Bureau of Animal Industry on Problems of Livestock Production. J. R. MOHLER. (*U. S. A. Dept. Agri. Miscel. Pub.* No. 81 Aug. 1930.)

The following extracts are taken from U. S. Department of Agriculture miscellaneous publication No. 81, dated August, 1930, written by J. R. Mohler, the experienced veterinarian who, as Chief of the Bureau of Animal Industry of the United States of America, has revolutionized the livestock situation of that country since the commencement of the present century. Being the mature conclusions of a scientifically trained expert in animal husbandry who has had unique experience, in dealing with the 200 million domesticated animals of the United States of America, and unparalleled opportunities of recording the results of all kinds of breeding programmes they are of exceptional authority. Dr. Mohler's work has been of immense economic benefit to the entire community of the United States of America and his conclusions, which moreover are in striking accord with the principles evolved by the practical stock-breeders of old, might safely be adopted by all concerned with livestock improvement in this country.

1. "Community effort in raising the same breed or variety of stock offers many advantages."

2. "In general, selection should depend on suitability of a breed for local requirements."

3. "The crossing of established breeds of livestock of different types seldom gives the results expected and is usually an undesirable practice."

4. "Similar types of livestock, particularly swine, when cross-bred, often make excellent anima for general utility and market purposes, but their offspring have such mixed heredity that they a practically useless in systematic herd improvement. Consistent work with one well chosen bre is more likely to give satisfaction and be profitable than attempts at cross-breeding."

5. "The establishment of new breeds of livestock involves years of the most skilful effort a well as extensive resources in funds and in large numbers of specially selected breeding animals."

6. "Persons inclined towards breeding activities along original lines can render more valuabl service to the industry by developing improved types of the established breeds."

7. "The bureau advises the castration and dehorning of market cattle."

8. "Silos are a valuable means of providing economical and succulent feed during winter and a times when pastures are inadequate."

9. "Research by qualified investigators is considered the most satisfactory way to solve man classes of livestock problems."

10. "The judging of livestock by competent authorities at fairs, shows, and other exhibition is an important means of bringing about high standards of excellence."

11. "Accurate statistical information is an important basis for planning livestock operation wisely and for verifying or correcting one's judgment of conditions bearing on the industry."

The Diagnosis of "Redwater" (Piroplasmosis) in Indian Cattle. HUGH COOPE and P. R. KRISHNA IYER. (*Ind. J. Vet. Science and Animal Husbandry*, 1 296-300.)

An account is given of the existing methods for the diagnosis of "redwater" in Indian cattle both during life and after their death and the limitations of these methods are briefly discussed.

It is not often possible to diagnose piroplasmosis in Indian cattle by microscopical examinatio of blood smears, or by the clinical symptoms regarded as characteristic of the disease. Nor is it possible to arrive at a correct etiological post-mortem diagnosis based upon lesions described in tex books.

Some original observations made by the writers upon morphological changes displayed by *B. bigemina* during the course of their disappearance after death of the host are described and a account is given of the writers' method of post-mortem diagnosis based, in the absence of othe lesions, upon a peculiar colour lesion of the kidneys. [Authors' abstract.]

Tick Infestation in the Coastal Tract of North Kanara District. R. N. NAIK. (*Ind J. Vet. Science and Animal Husbandry*. 1, 301-322.)

The writer has carried out an investigation into the extent and intensity of tick infestation i the coastal tract of North Kanara District, and has found that the infestation constitutes one of the most serious scourges that the livestock owner has to contend with.

The following species of ticks have been found by him to occur in the tract referred to :—

(1) *Haemaphysalis bispinosa*, Neumann. (2) *Haemaphysalis spinigera*, Neumann (3) *Boophilus australis*, (Fuller). (4) *Rhipicephalus haemaphysaloides*, Supino. (5) *Amblyomma integrum*, Karsch. (6) *Hyalomma aegyptium ssp isaaci*, Sharif.

Certain facts are discussed concerning the correlated influence of climatic conditions on tick metabolism and infestation. Tick infestation has been found to attain its highest intensity during

wet and hot-damp seasons; a temperature of 75°F to 85°F with a humidity of 75 to 90 per cent. has been found to be the optimum condition for the accelaration of the metamorphosis of ticks found in the tract, this being in conformity with the "water-optimum" theory propounded by Headlee (1917).

Apart from the various injurious effects now known to be caused by ticks and dealt with at some length in the present paper, the writer refers to a new condition—termed by him, tick toxaemia—which would appear to be caused by the toxicity of the saliva injected by ticks during the act of feeding.

The problem of tick infestation in North Kanara District assumes a position of paramount importance by reason of the enormous loss it causes to the stock-owner. The average rate of mortality due to it alone has been estimated at not less than 5 per cent. The quinquennial cattle census for the last 15 years has revealed that on account of this infestation there has been no increase in the cattle population of the tract during this period, in spite of the fact that not more than 100 animals have been slaughtered for meat annually and that more than 3,000 animals have been imported every year.

Suggestions are made concerning remedial and control measures, including the introduction of arsenical dips, which have appeared to the writer most suitable for adoption in these tracts, having regard to the economic condition of the people. [Author's abstract.]

"Interim Report on the Immunization of Draft Animals in Burma against Anthrax". D. T. Mitchell. *Superintendent, Government Printing and Stationery, Rangoon, 1930.*

An account of experimental work on elephants, buffaloes and cattle. Spore vaccine was made from the Bovine Vaccine Strain used at Onderstepoort, South Africa. Virulent material was prepared from a strain obtained from an elephant in Burma. Preliminary sheep tests showed that the vaccine immunized against 1000 sheep M. L. D. of the virulent material.

During Mitchell's absence from Burma nineteen elephants were inoculated. "Two developed large swellings at the inoculation site, and one died from some complicating factor". On his return to Burma Mitchell inoculated four mature elephants subcutaneously with his spore vaccine. A was given 2 cc. followed by 2 cc. after 11 days, B 1 cc. followed by 1 cc. after 14 days, C 2 cc. and D 1 cc. A received 1000 Sheep M. L. Ds. 55 days, and B, C, and D received 1000 M. L. Ds. 67 days after the first injection. Except for a slight thermal reaction after 18 hours by B and D, all remained fit.

1000 sheep M. L. Ds. of virulent material killed one goat in 36 hours, another goat in 30 hours, one elephant in six days and a second elephant in 4 days.

Mitchell concludes that anthrax vaccine from South African Bovine Vaccine strain is safe for elephants and gives an absolute protection against 1000 sheep M. L. D. of virulent elephant strain.

The same vaccine in doses of one cc. was used for cattle and buffaloes, including lactating animals, without any ill effect. No immunity tests were carried out. [G. P.]

NOTES

SUGAR IN JAMAICA

According to the Annual Report of the Department of Agriculture, Jamaica, for the year ended 31st December, 1930, the year under review was a difficult period for the cane planters owing to the world-wide depression in trade, the difficulties of selling Island produce, the low level of prices which were much below the cost of production and the insufficient rainfall which was below the average. But in spite of these difficulties, a record crop of sugar was obtained. Over 47,000 tons sugar was exported during the year, which represents one of the largest crops since the installation of the vacuum pan process in place of the old muscovado system of sugar manufacture. The losses to the planters, however, have been substantially reduced owing to the bounty of £2 per ton paid by the Colonial Government for the crop of 1930 and the pooling of the market for local grocery sugars. The record crop of 1930 is attributed to the recent development of large areas of sugar lands in Jamaica by means of deep mechanical tillage, irrigation, the substitution of new canes for the old Jamaica cane and the rational use of fertilizers mainly nitrogenous in character. The Barbados seedling BH (10) 12, amongst the new canes, has now generally displaced the White Transparent as the standard cane of Jamaica. P.O.J. 2725, P.O.J. 2727 and P.O.J. 2714 of the hybrid canes from Java have been successful on many cane lands. During the past year "P.O.J. 2878" known as the "Wonder Cane" of Java has been issued to every estate in the Island and to many small settlers. In Vere the Java cane E.K. 28 gave the record yield of 78 tons per acre which is about double the yield of the old estate cane. The Co. 281 and Co. 213 were not found to be promising under the local conditions but it is reported that a further trial is being given them.

Mosaic disease is gradually decreasing due to more attention being paid by the planters to rogueing and selection of healthy tops for planting and to the increasing cultivation of resistant varieties. The P.O.J. varieties are steadily displacing the Uba which was extensively planted for eradication of the mosaic disease.

At the request of the Sugar Board in Jamaica a special investigation is being conducted into the possibility of the utilization of locally made white sugar for preserving and canning purposes. (R. C. SRIVASTAVA.)

POLLINATION IN BAJRI (*Pennisetum Typhoideum*).

An interesting fact was observed in *bajri* grown for plant-breeding purposes out of the normal season (*i.e.*, in the month of May, 1931). It was seen that none of the unbagged earheads in the field produced any grain, the cause being apparently the lack of fertilization ; while those earheads that were bagged produced seed which showed distinct improvement in size and colour over what is got in the normal monsoon season. Non-fertilization in the unbagged heads was possibly due to the premature withering of the stigmas exposed to hot dry winds. In the bagged heads the stigmas were protected and hence probably receptive. The cause of the better size and lustre of the seed produced in these bags remains unexplained.

With the advent of rains, seed-setting began on the tillers that were then produced, indicating the probable correctness of the theory of the drying of the stigmas being one of the causes of non-fertilization in hot weather. (D. B. Barve.)

GROWTH-RATE OF CALVES AT KANKE FARM.

The attached chart shows the growth of calves in the Kanke Farm herd from the date of birth to a year old : the work was commenced in 1928 and it is easily seen that there was a very large improvement in 1929 though the scale of rations remained unaltered. The increase is probably due in large measure to the greater interest taken in the care of the calves as the result of the monthly weighings. The figures for 1930, which of course will not be complete until the end of the year 1931, seem to indicate a still further increase. The 1928 curve represents the average growth of about 55 calves, while the 1929 curve was obtained from about 65 calves.

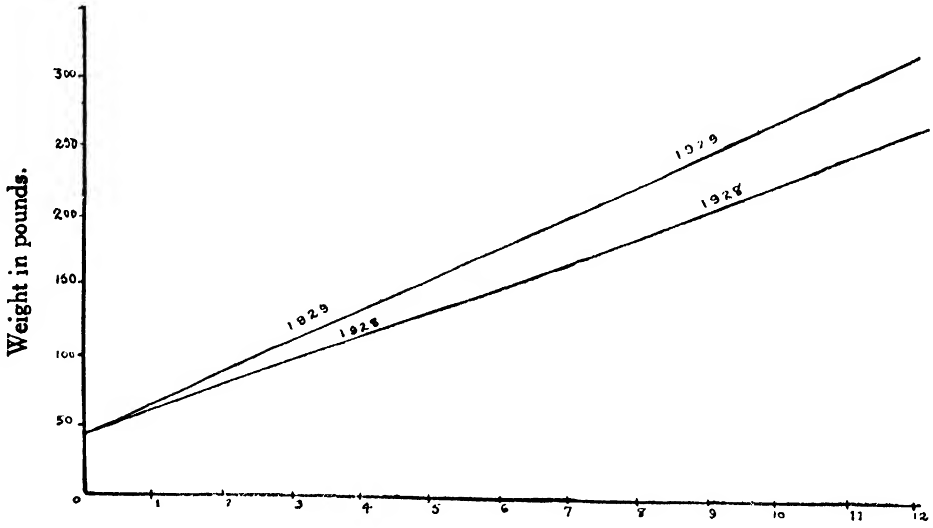
The lines were obtained as follows :—

(1) All calves were weighed at birth and thereafter on the first of every month ; they were placed in categories of 0-15, 15-30, 30-45, days old and so on up to 375 days.

(2) When the last calf born in each year was a year old, the weights for all the fortnightly periods were totalled and averaged, and the results plotted on squared paper.

(3) A smooth line was then drawn through the points thus obtained.

Live weight of calves—Kanke Farm.



Age in months.

A copy of the diet sheet in force at that time is also given. (This has been slightly modified during the present year). As regards fodder, the calves received green food *ad lib* from August up to December, but thereafter paddy straw was the main fodder given to them : the quantity was graduated according to the age of the calves, the oldest group receiving five pounds per head per day. [C. A. MACLEAN.]

Calf Diet Sheet—Kanke Farm.

Age	Daily milk ration	Grain Ration		Remarks
		Daily allowance	Composition	
Up to one month old	Commencing at ⅛ of body weight and increasing by one pound per week, but never to exceed 12 lbs.	Increasing from ¼ lb. at 2 weeks old to 2½ pounds at four months old.	Linseed cake 1 part Cereal 1 „ Pulse 1 „ Bran 1 „	The milk is fed in 3 meals during the first month : in two meals during the 2nd and 3rd months. In the 4th month the evening meal is discontinued.
2nd month	10 lbs. . .	..		
3rd „	8 „ . .	..	..	
4th „	4 „ . .	..	..	
5-6th „	..	3 lbs. . .	..	
7-9th „	..	3½ „ . .	..	
10-12th „	..	4 „ . .	.	

NOTE.—The cereal and pulse fed depends on prevailing prices.

REDUCING COSTS.

Adjustment to meet the situation created by low prices and high costs continues to be the outstanding problem with which farmers are at present faced. Whatever may be the main cause or causes of agricultural depression, in seeking a remedy farmers must primarily look to reduced costs of production and particularly of distribution. In a recent paper on the economic outlook for agriculture in the United States, Dr. Warren (Cornell) states that if the trouble is over-production the charge that extension work and scientific research are to blame may have a grain of truth in it, but if, as he himself contends, the trouble is mainly monetary, and if we must learn to produce at a profit with prices at pre-war levels and wages far above pre-war, then there was never before a time when research and education should be pushed with more vigour. Farmers must know how to adjust and act quickly. The use of improved machinery and greater output per man are the chief means by which the depression can be met.

Dr. Warren anticipates still lower prices except for products that are already below the general price level. He counsels the American farmer neither to buy land nor to work land that does not give a high output per hour of labour. The farmer should have a business large enough to employ fully all his time and that of his employees. He must get more bushels of grain and more pounds of milk per unit of labour. The higher crop yields should be obtained by dropping out of use the fields that do not give high yields. Such fields may be used for pasture. The fields that are used for cultivated crops should be well fertilized and well cared for. Fertilizers are cheap, but wages are high. More care in using good seed, attention to disease control and the like are essential. Such changes mean more production per man.

Occasionally, Dr. Warren points out, as in Western Kansas, a region of low yields can be used because a new machine comes in and makes the output per man very high with low yields. Even here, however, high yields for the region are very important. Labour may be made more efficient by the use of machinery, but labour-saving plans are often the more important consideration. Methods of doing work at the time, and in the manner, that make an hour count for the most are of unusual value.

The discrepancy between producers' prices and consumers' prices is, he considers, particularly severe on agriculture because the farmer, as a rule, buys retail and sells wholesale. It is, therefore, all-important that farmers should attempt to get nearer to consumers and to whole-salers when, respectively, selling and buying.

When in the past nearly all the time of human beings was spent in obtaining bare necessities, quality of food was not very important, but decade after

decade as the proportion of income that goes for food is reduced, the increased buying power is in part spent on choicer foods. Even in the general depression that prevails there is a demand for quality.

Finally, Dr. Warren pleads that agricultural colleges should take an active part in studying distribution. The colleges were originally biological institutions. When farming was a home industry the problems of production were the primary ones. The rising price level, from 1900 to 1920, also made production particularly important. Now the subjects of Farm Management, Marketing, Prices, Accounting, and Public Affairs are as important as production. [Reprinted from the *Journal of the Ministry of Agriculture*, Vol. *XXXVIII*, No. 6, September 1931.]

MANY NEW RECORDS IN EMPIRE BUYING.—EMPIRE MARKETING BOARD'S REPORT.

An Active Year.

A steady increase in the sales of Empire produce in the United Kingdom is recorded in the Annual Report of the Empire Marketing Board just published.

" The growing habit of buying from within the Empire has attained an impetus in the United Kingdom ", states the Report, " which even the world-wide economic depression has been powerless to retard ".

Twenty-two commodities, drawn from four Dominions and several Colonies, were noted in the Annual Report of the Empire Marketing Board for 1928-29 as having been imported into the United Kingdom in the previous two seasons in greater quantities than ever before in their histories. Again, the Board's Annual Report for 1929-30 showed that twenty-five new records had been set up, in the year then under review, by Empire foodstuffs, as regards volume of imports into the United Kingdom. Nearly half these did even better in the year now being considered, while a further substantial list of Empire foodstuffs established records. Apples from Canada and from New Zealand reached this country in record quantities in 1930, as did bananas from the British West Indies, butter and cheese from New Zealand, coffee from British East Africa, currants from Australia, eggs from Australia and South Africa, grape fruit from South Africa and Palestine, lamb from New Zealand, oranges, peaches, plums, sugar and wine from South Africa, pears from no less than four Dominions, and tobacco from India.

A number of other foodstuffs are also mentioned in the Report for which, while the 1929 record was not reached in 1930, the last year's imports surpassed all previous years, except 1929. These include Australian raisins and sultanas, New Zealand frozen pork, Ceylon tea, Australian sugar and British Malayan canned pineapples.

CHANGES IN PUBLIC TASTE.

The people of the United Kingdom are proving themselves steadily more willing to buy from within the Empire. Many factors have combined to bring about this encouraging result. First, more scientific attention is being paid to-day than ever before by Empire producers to the need for supporting the natural high quality of their goods by grading and orderly marketing in all its branches. Secondly, distributive traders of all kinds in the United Kingdom have shown themselves wholeheartedly resolved to further the progress of Empire buying along sound economic lines. Thirdly, the contact between producers overseas and wholesale and retail traders in the United Kingdom grows steadily closer. Fourthly, consumers in the United Kingdom, men and women, are becoming more aware of the excellent and wide range of Empire products and of the importance of Empire buying.

EXTENSIONS RECOMMENDED.

When the Imperial Conference met in 1926, the Board was only a few months old, so the Conference of 1930 was the first to be held since the Board began actively to perform its functions. The Conference passed the Board under review and adopted a number of resolutions affecting its present and future activities. Surveying the Board's work since its inception in 1926 the Conference expressed itself as satisfied that it is valuable to the Commonwealth as a whole, and recommended its continuance and its extension in certain directions, notably in the spheres of market intelligence, statistical surveys and market promotion. The Conference noted and approved the Empire Marketing Board's programme of research, involving commitments approaching £2,000,000 from the Empire Marketing Fund, as well as independent contributions by Empire Governments.

A REGIONAL "SALES DRIVE".

Another extension of what may be regarded as the Board's more directly commercial activities in the field of Empire marketing is instanced in a special campaign which was undertaken, at the beginning of 1931, in Lancashire with a view to increasing the sales of home and oversea Empire butter in that area. Here long established prejudice in favour of casked butters of pale colour was held to be too deeply entrenched to permit an effective distribution being made of Empire butters, particularly those from Australia and New Zealand. The Board decided that, as large supplies were available of butter of first-rate quality from these Dominions, an effort should be made to overcome this sales resistance by a definite appeal to the distributive trades. The Board, therefore, called into consultation the London Managers of the Australian and New Zealand Dairy Produce Boards and invited their co-operation in a concerted effort.

An office was accordingly opened by the Board in Manchester early in January. Calls were made, in the first instance, upon the importers and wholesalers in Liverpool and Manchester and their co-operation in the scheme secured.

The Board's officers then proceeded to call upon every retailer in Manchester and certain other Lancashire towns in order to influence those who did not at present stock Empire butters. The results of the campaign have been remarkably successful, 2,940 shops out of 6,620 visited were selling Empire butter when the campaign began, while, before it closed, the number had risen to 4,903, an increase of 2,000 shops selling Empire butter. The close co-operation of the two Dominion Dairy Produce Boards unquestionably contributed to this success. There is clear evidence that the old prejudices against boxed butters have been broken down---it is hoped permanently. The experience gained in this experiment of employing travellers without samples in close co-operation with the representatives of the oversea producers encourages the Board to believe that they have here a field capable of considerable extension. Indications suggest that the continued use of the three methods of approach, which have been a feature of the past year's work in the field of marketing promotion, may materially contribute to the Board's success.

PUBLICITY.

Eight methods of publicity have again been used.

First, advertisements have been inserted in the national press and in trade and local papers.

Secondly, posters have been displayed on the 1,750 frames distributed over 450 towns. The sets of posters have been changed seventeen times in the year. Hoardings were used at Birmingham. Reproductions of suitable posters with leaflets were issued to 22,000 schools in the United Kingdom which had applied for them.

Thirdly, display material for shops has again been sent out and leaflets, both for housewives and for schools, have been issued in great quantities.

Fourthly, lectures have been given.

Fifthly, wireless talks to housewives have been arranged, by courtesy of the British Broadcasting Corporation, following which 20,000 individual applications were received for leaflets. The Chairman of the Board and of the Research Grants Committee both gave talks in connection with the Board's work.

Sixthly, the Board has taken part, extensively, in exhibitions and shopping weeks.

Seventhly, meetings of business men, traders and producers have been addressed.

Eighthly, the distribution of films through theatrical and other channels has been developed.

THE BOARD'S METHODS.

Each of the methods hitherto employed by the Board for the furtherance of Empire marketing has again proved valuable in 1930-31. The policy of making grants for scientific research work in the United Kingdom and in the oversea Empire has been continued. Economic investigation and market enquiries have been carried out on a more intensive scale; and publicity, in all its branches, has been used to popularise the wisdom of Empire buying. It has always been the Board's view, in every Empire country, Empire buying begins at home; and the fact that the producers of the United Kingdom have first claim in their own country on the home consumer has, as always, been stressed in the Board's appeal.

MARKET INTELLIGENCE.

The importance of collecting information as to supplies of Empire and foreign commodities available from week to week, and of disseminating such information as widely as possible among Empire producers and others concerned in Empire trade, has been fully appreciated by the Board. The issue of weekly notes for the fruit and dairy produce trades has been extended. The latter include figures, hitherto unavailable, of butter in cold storage, and these have made possible a study of the consumption of imported butter, which in the first five months of 1931 was found to have risen by about 14 per cent. over the corresponding period of previous year—an increase almost entirely derived from Empire sources.

CONSUMERS' PREFERENCE.

The Board's machinery for testing the differing market requirements of the United Kingdom has been extended and a number of investigations have been conducted and their findings made available to producers and others concerned. Experimental shipments of Empire commodities which might find a market in the United Kingdom have been organised in co-operation with the authorities in the countries of origin. Studies of wastage in transit have been made.

TWO EMPIRE SHOPS.

The year has been notable for outstanding activity in this field. The experiments tried at Glasgow in the previous year of popularising and extending the sale of Empire produce by the opening of a shop, in which samples were sold to the public under conditions which secured the goodwill and co-operation of the trades

proved definitely successful. A similar shop was, therefore, opened in Birmingham in January of this year, and plans are under consideration for acquiring the tenancy of other shop premises in various centres for periods not exceeding six months. These shop experiments have the merit of affording an opportunity to Empire countries in turn of making a special display of their produce in surroundings which are designed to stimulate public interest and under conditions which, thanks to the keen interest taken by the distributive trade, are likely to be productive of permanent results. The temporary establishment of an Empire shop in a particular district also provides a centre at which the publicity and marketing activities both of the Board and of the Governments concerned can be strikingly concentrated.

THE COLLECTIVE CONSUMER.

The Importance of securing the practical interest of the large buyers of foodstuffs, such as local authorities, institutions, hotels, shipping companies and other bodies which undertake catering on a large scale, has been recognised from the outset, and tentative steps to develop this field of activity have been taken on more than one occasion. During the past year the Board felt justified, as a result of the experience they had gained since their formation, in beginning serious effort in this field. A special staff was, accordingly, appointed to call upon local authorities, after suitable introduction, and to discuss with them the extent to which their purchases of Empire goods might be increased. This experiment has already proved to be fully justified. The reception accorded to the Board's officers by local authorities all over England and Wales has been most encouraging, and some two hundred authorities have invited the Board to submit suggestions for incorporation in their tender forms, when these are under revision. The new forms of tender become operative, in the majority of cases, on the 1st April. It is too early yet to judge of the full effect of the changes which have been made as a result of the advice tendered by the Board, but there is no doubt that the purchasing power of local authorities is in course of being mobilised in the interest of Empire trade in no uncertain fashion.

INDIA BY THE ENGLISH SEA.—A FRONT WINDOW SEEN BY TENS OF THOUSANDS.—EMPIRE MARKETING BOARD'S LATEST SHOP.

Another front window in England has been filled with Indian produce. This is at Blackpool—in many ways the most remarkable seaside centre in the old country—where the Empire Marketing Board have opened a shop for the holiday season. The two previous Empire Marketing Board shops have been in Glasgow and Birmingham and have carried on, for six months each, the good work of putting Indian produce directly under the eyes of old country housewives. Striking success

PLATE I.

Blackpool—on the Front.

PLATE II.

The Mayoress Accepts a Gift of Indian Chutney.

attended these ventures. Now, at Blackpool, a new experiment has been launched. The aim here is to catch crowds from all the many scattered industrial towns of Lancashire and Yorkshire who flock to Blackpool when the "Wakes" are in full swing.

Blackpool is the Mecca of North country folk on holiday, and such is its reputation that it draws thousands of visitors from the Midlands and the South as well. That is why the Empire Marketing Board have chosen a central site on the sea front and just by the famous Tower, and are handing these commanding shop premises to the Empire countries, in turn, to display their goods, and sell samples and, by every kind of enterprise, to extend their markets.

India's tenancy of the Empire Shop coincides with a great display of illuminations, which are attracting more visitors than ever to this fovourite seaside town.

Indian energy.

It would be impossible to open shops in every industrial town. The expense and the strain on staffs would be prohibitive. But, in Blackpool, visitors from Wigan and Batley, from Halifax and Preston and from a wider area still, pass through between July and October and none of them can miss the Empire shop. There they are invited to test the excellence of Indian produce and, if they approve (and who doubts that they will ?) to make it part of their daily shopping when their holidays end and the trains or charabancs take them home. In the first week of India's display more than 6,000 samples of Indian produce were sold.

The Indian show is a triumph for the energy and experience of the officials of the office of the High Commissioner for India who have staged it and it has had a good "send-off" from the Mayor of Blackpool who welcomed Mr. William Lunn, the Under-Secretary of State for Dominion Affairs, at the opening.

Nobody who has not seen the masses of people, thick on the wide sands, up and down the several miles of front and in the enormous pleasure resorts, like the Tower and the Winter Gardens, can picture what Blackpool is like at this season. No Empire shop window ever opened on to such a scene before. This is a unique chance for India and full advantage is being taken of it. [From a correspondent, Blackpool, England.]

Personal Notes, Appointments and Transfers, Meetings and Conferences, etc.

The Council of State has under rule 1 (12) of the Rules and Regulations of the Imperial Council of Agricultural Research elected the Hon'ble Dewan Bahadur G. Narayanaswami Chetti Garu, C. I. E., as its representative on the Imperial Council of Agricultural Research in the vacancy caused by the appointment of the Hon'ble Sir C. P. Ramaswami Aiyar, K. C. I. E., as a temporary member of the Council of the Governor-General of India.

Sir Purshotamdas Thakurdas, Kt., C. I. E., has been nominated by the East India Cotton Association to be a member of the Indian Central Cotton Committee, Bombay, *vice* Major W. Ellis Jones resigned.

The services of Mr. P. H. Rama Reddy, I. A. S., (Madras) have been replaced at the disposal of the Indian Central Cotton Committee, Bombay, for appointment as Deputy Secretary to the Committee with effect from the forenoon of the 29th July 1931.

In modification of the Education, Health and Lands Department notification No. 593-Agri., dated the 9th April 1931, Dr. F. J. F. Shaw, Imperial Economic Botanist, Pusa, has been granted leave on average pay for 6 months and 6 days, combined with leave on half average pay for 24 days, with effect from the afternoon of the 18th March 1931.

Mr. W. Smith, Imperial Dairy Expert, has been granted leave on average pay for 16 days, with effect from the 26th September 1931, and has been permitted to retire from service on the expiry of the leave, *i.e.*, with effect from the 12th October 1931.

Mr. Z. R. Kothavala, Assistant to the Imperial Dairy Expert, has been appointed to act as Imperial Dairy Expert, with effect from the 26th September 1931.

DR. B. B. MUNDKUR, M. A., PH. D., has been appointed on probation as Class II Assistant in the Mycological Section of the Imperial Institute of Agricultural Research, Pusa, with effect from the forenoon of the 11th September 1931.

MR. F. J. SHIRLAW, M. R. C. V. S., Professor of Pathology and Bacteriology, Punjab Veterinary College, has been appointed as Temporary First Veterinary Research Officer, Imperial Institute of Veterinary Research, Muktesar, with effect from the afternoon of the 17th June 1931.

Madras.

Rao Sahib Y. RAMACHANDRA RAO, M. A., F. E. S., on reversion to service under the Madras Government, has been appointed to be Entomologist to the Government of Madras, Coimbatore.

Dr. T. V. Ramakrishna Ayyar, B.A. (Mad.), Ph. D. (Stanford), F. E. S., F. Z. S., Officiating Entomologist, on relief by Rao Sahib Y. Ramachandra Rao, has been appointed to be Lecturer in Entomology, Agricultural College, Coimbatore.

Mr. M. C. Cherian, B.A. (Mad.), B. Sc. (Edin.), D. I. C., on relief by Dr. T. V. Ramakrishna Ayyar, has been appointed to be Assistant Entomologist, Coimbatore.

Mr. V. Ramanatha Ayyar, L. Ag., Superintendent, Agricultural Research Station, Koilpatti, and officiating Cotton Specialist, on return from leave, has been appointed to officiate as Superintendent, Cotton Breeding Station, Coimbatore.

Mr. R. Chockalingam Pillai, L. Ag., Superintendent, Cotton Breeding Station, Coimbatore, on relief by Mr. V. Ramanatha Ayyar, has been appointed to officiate as District Agricultural Officer, Tinnevelly.

Mr. D. Balakrishnamurti, Dip. Agri., Deputy Director of Agriculture, Second Circle, has been granted leave on average salary for two months and five days preparatory to retirement with effect from 11th October 1931.

The following officers have been appointed to be members of Madras Veterinary Service with effect from 1st August 1931 :—

(1) Mr. C. Suryanarayana Murthi, G.M.V.C., Acting District Veterinary Officer, Rajahmundry.

(2) Mr. T. S. Alagappa Pillai, G.M.V.C., Acting District Veterinary Officer, Madura.

(3) Mr. A. L. N. Somayajulu Pantulu, G.M.V.C., Acting District Veterinary Officer, Nellore.

Bengal.

Khan Sahib Saiyid Sultan Ahmad, Officiating Director, Civil Veterinary Department, has been granted leave on average pay for five months with effect from the 15th October 1931, or any subsequent date on which he may be relieved.

Punjab.

Sayed Riaz-ul-Hassan, P. V. S., Assistant to the Professor of Pathology at the Punjab Veterinary College, Lahore, has been granted study leave for one year, combined with leave on half average pay for 15 months from 16th September 1931 to the 15th December 1933.

The services of Khan Bahadur M. Fateh-ud-Din, B.A., M.R.A.S., A.R.H.S., I.A.S., Deputy Director of Agriculture, Jullundur, have been placed at the disposal of the Government of India for a period of three months, with effect from the 25th July 1931.

Mr. H. G. Sadik, B. A. (Oxon.), Extra Assistant Director of Agriculture, Jullundur, has been appointed officiating Deputy Director of Agriculture, Jullundur, with effect from 25th July 1931, *vice* Khan Bahadur M. Fateh-ud-Din whose services have been placed at the disposal of the Government of India.

Major E. M. Nicholl, O.B.E., M.R.C.V.S., Research Officer, Civil Veterinary Department, Punjab, Lahore, resigned his appointment with effect from 28th September 1931, forenoon, on the expiry of his two months and 18 days' leave.

Dr. Ramji Narain, D.Sc. (Pb.), Assistant to the Agricultural Chemist to Government, Punjab, Lyallpur, has been granted combined leave for two years with effect from 22nd September 1930.

Mr. P. N. Nanda, M.R.C.V.S., Assistant Superintendent (Stock), Government Cattle Farm, Hissar, has been transferred to Ambala with effect from 28th July 1931 (forenoon).

Mr. R. R. Ghulati, M.R.C.V.S., Superintendent, Civil Veterinary Department, Ambala Division, Ambala Cantonment, has been transferred to Hissar with effect from 1st August 1931 (forenoon).

Bihar and Orissa.

Mr. P. G. Malkani, Research Officer and Professor of Pathology and Bacteriology of the Bihar and Orissa Veterinary College, has been appointed to be a member of the Bihar and Orissa Agricultural Research Committee in place of Rai Sahib Priya Nath Das.

Central Provinces.

Consequent on the abolition with effect from the 11th August 1931, of the temporary post of Deputy Superintendent, Civil Veterinary Department, created for the Serum Simultaneous method of inoculation for rinderpest, Mr. M. James, G.M.V.C., Officiating Deputy Superintendent, Civil Veterinary Department, has been reverted to his substantive post of Veterinary Inspector.

REVIEWS

"Amchi Sheti" (Our Agriculture), a Marathi book, by K. S. KULKARNY, B. AG., Assistant Professor of Agriculture in the Poona College of Agriculture. Arya-Bhushan Press, Poona. Price Rs. 3.

There has been recently a healthy development of literature in Indian languages concerning agriculture and the sciences underlying it. Books on gardening, insect pests and vegetable culture have appeared in the past few years. With a view to encourage this excellent movement and also to provide reading matter of a useful kind for those who had just left school and taken up a vocation, the Government of Bombay in 1928 appointed a committee to make proposals for suitable books, outline their contents and select authors. This committee on agriculture was one of three dealing with literature in general, There were two others, one specially charged with the subjects of History and Geography, and the other with the subject of Domestic Science. Financial assistance on a definite limited scale was given by Government to the authors on completion of their work.

The book under review which has been written under these condition is a comprehensive but not unduly large work in the Marathi language on agriculture in general. The author, one of the professorial staff in the Poona College of Agriculture, has had much experience of the subjects with which he deals, and also of modes of presenting agricultural knowledge both in the lecture room and in Marathi journalism, as he has been editor of the Marathi agricultural magazine "Shetki ani Shetkari" (Agriculture and the Farmer) for several years. In the general plan of the work, soils, their nature and treatment are first dealt with. This naturally brings in the question of implements. Then the other factors in the environment of crop plants are treated, *e.g.*, water, manure, diseases, etc. A very useful section is devoted to farm accounts, a subject that is generally ignored. Then follows a section dealing with each crop individually, and a final chapter on village sanitation.

The arrangement is thus logical and scientific. The treatment of each section combines local experience of existing practices with the best suggestions of modern science. There is no blind application of scientific knowledge because of its mere modernity, and there is no rejection of traditional wisdom on account of its mere antiquity. The book is a happy blend of science and practice, which is after all, what agriculture itself should be.

The book which consists of about 300 pages crown octavo has been printed by the Arya-Bhushan Press, Poona, and is copiously illustrated. The price of the

book (Rs. 3) is very moderate considering its size, its make-up, and the authoritative nature of its contents. [W. B.]

Herbage Abstracts, June, 1931.

The first number of the new quarterly publication—Herbage abstracts of the Imperial Bureau of Plant Genetics : Herbage Plants, Agricultural Buildings Aberystwyth, Wales, has just been received. This publication will deal with herbage and certain forage crops not only from the point of view of the plant breeder but also from that of the agronomist. Such subjects as field trials, seed production, weed control and all aspects of grassland and pasture management will be dealt with rather fully, while information regarding morphology, physiology, ecology, etc., will be introduced when it is considered desirable. Each number will also contain a section of miscellaneous notes, short extracts from official reports and proceedings of conferences, which might be of value to the worker on herbage and forage crops and general grassland.

At present the majority of the papers and reports abstracted deal with the more temperate regions but, as the study of tropical grasslands and forage crops develops, it is hoped that it will be possible to supply more information for such conditions. The subscription for Herbage Abstracts is 1*s*. 6*d*. per copy or 4 shillings for the year 1931 (3 issues only) and thereafter 5 shillings per annum for four issues. [D. M.]

"Lucerne Inoculation, and the Factors affecting its Success" by H. G. THORNTON, D. Sc., Imperial Bureau of Soil Science. Technical communication No. 20, 39 pp. H. M. Stationery Office, 1*s*. 6*d*. net.

Dr. Thornton is the Chief Bacteriologist of Rothamsted Experimental Station, England, and more than any other worker, he has been instrumental in advancing the successful use of bacterial inoculation in the growing of lucerne in England.

The booklet contains a short summary of the researches that led up to the discovery that the enrichment of nitrogen in the soil, following the growth of a leguminous crop, was due to the action of nitrogen-fixing bacteria in the root nodules of the legumes. It has further been shown that the presence of the bacteria is essential for the healthy growth of the host plant, and the frequent failure of lucerne, under apparently suitable soils and climatic conditions, is often attributable to the absence of the necessary organism from the soil. The idea of "inoculating" unsatisfactory soils dates back to 1887, but it is only recently that the practice has come into prominence, owing to the success following improved methods of technique in the preparation and application of the bacterial cultures.

Dr. Thornton gives full details of both the scientific and practical aspects of modern lucerne inoculation, with some remarkable figures illustrating the success of its use in England. Similar success has followed inoculation in many of the Dominions, although carefully controlled experiments have not been made on any large scale. Dr. Thornton believes that there is great scope for its use overseas, especially in tropical countries.

The Communication should receive the serious attention of all interested in the growth of lucerne.

NEW BOOKS

On Agriculture and Allied Subjects

Agricultural Progress. Vol. VIII, 1931. Pp. 169., (London: Ernest Benn, Ltd., Bouverie House, E. C. 4) Price 5*s.* net.

Progress in English Farming Systems—V. A Pioneer of Progress in Farm Management. By C. S. Orwin, Agricultural Economics Research Institute, Oxford. (Oxford: The Clarendon Press.) Price 1*s.* 6*d.* net.

Co-operation in Danish Agriculture. By Harald Fabar. An English Adaptation 'Andelsbevoe gelsen' 'Danmark', by H. Herkel. New Edition. Pp. xxii +188. (London, New York and Toronto: Longmans, Green and Co., Ltd., 1931.) 9*s.* net.

An Economic and Financial Analysis of Sixteen East Anglian Farms, 1927-29: with special reference to the Economic Aspects of the Rationing of Livestock. By W. H. Kirkpatrick (University of Cambridge, Department of Agriculture, Farm Economics Branch: Report No. 17). Pp. 30. (Cambridge: W. Heffer and Sons, Ltd., 1931.) 1*s.* net.

Vegetable Crops. By Homer C. Thompson. Second Edition. Pp. 560 (New York: McGraw-Hill Book Co., Inc; London: McGraw-Hill Publishing Co., Ltd., 1931). 25*s.* net.

Gardening day by day throughout the year. By Philip West. Pp. 214. (London: Harold Shaylor, Ltd., 1931.) 3*s.* 6*d.* net.

Perennial Gardens. By H. Stuart Ortloff. Pp. vi+88. (New York: The Macmillan Co., 1931). 5*s.* 6*d.* net.

Honey Craft: in Theory and Practice. By J. A. Lawson. Pp. xii+228+19 plates. (London: Chapman and Hall, Ltd., 1931.) 6*s.* net.

The Principles of Dairying, Testing and Manufactures. By Henry F. Judkins. Second Edition. revised by Richard W. Smith, Jr. (The Wiley Agricultural Series.) Pp. xvii+322. (New York: John Wiley and Sons. Inc.; London: Chapman and Hall, Ltd., 1931.) 15*s.* net.

Australian Dairyman's Handbook. By Ralph S. Maynard. With contributions by many of the most eminent Experts in Australia. Pp. xx+690. (Sydney: Angus and Robertson, Ltd.; London: Australian Book Co., 1931.) 45*s.* net.

An Introduction to Plant Physiology. By W. O. James. Pp. viii+260. (Oxford: Clarendon Press; London: Oxford University Press. 1931.) 7*s.* 6*d.* net.

Plant Physiology: with reference to the green plant. By Edwin C. Miller. Pp. xxiv+900. (New York: McGraw-Hill Book Co., Inc.; London: McGraw-Hill Publishing Co., Ltd., 1931.) 35*s.* net.

Life Movements in Plants. Edited by Sir Jagadis Chunder Bose. (Transactions of the Bose Research Institute, Calcutta, Vol. 6, 1930-31.) Pp. VI+211. (London, New York and Toronto : Longmans, Green and Co., Ltd., 1931.) 18*s.* net.

Text-book of General Biology. By Waldo Shumway. Pp. VIII+361. (New York : John Wiley and Sons, Inc. ; London : Chapman and Hall, Ltd., 1931.) 15*s.* net.

Heredity. By A. Franklin Shull. (McGraw-Hill Publications in the Zoological Sciences.) Second Edition. Pp. XV+345. (New York: McGraw-Hill Book Co., Inc.; London : McGraw-Hill Publishing Co., Ltd., 1931.) 15*s.* net.

The Philosophical Basis of Biology : Donnellan Lectures, University of Dublin, 1930. By J. S. Haldane. Pp. X+169. (London : Hodder and Stoughton, Ltd., 1931.) 7*s.* 6*d.* net.

Laboratory Manual of Physiological Chemistry.. By Marion Fay and Meyer Bodansky. Second Edition, revised. Pp. IX+260. (New York: John Wiley and Sons, Inc. ; London : Chapman and Hall, Ltd., 1931.) 10*s.* net.

Recent Advances in Analytical Chemistry. Vol. 2: Inorganic Chemistry. Editor : C. Ainsworth Mitchell. Contributors : Norman Evers, B. S. Evans, S. G. Clerke, W. R. Schoeller, A. T. Etheridge, Brynmoor Jones, A. R. Powell, Janet Warden Brown, J. W. Haigh Johnson. Pp. XIV+452. (London : J. and A. Churchill, 1931.) 15*s.* net.

Agricultural Engineering. By T. B. Davidson. Pp. VI+396. Illustrated (New York: John Wiley and Sons; London: Chapman and Hall). Price 17*s.* 6*d.* net.

The Reclamation of Land from the Sea. By F. M. Duplate-Taylor, M. Inst. C. E., M. I. Mech. E., M. I. Struct. E., M. Cons. E., M. Soc. I. C. (France). Introduction by Sir George L. Courthope, Bart., M. C., M. P., D. L. Pp. 153+83 figs. (London : Constable & Co., Ltd. 1931.) 21*s.* net.

Land Drainage and Flood Protection. Bernard A. Etcheverry. Pp. 327. (New York : McGraw-Hill Book Co., Inc. ; London : McGraw-Hill Publishing Co., Ltd., 1931.) 15*s.* net.

Elements of Practical Statistics. By. F. H. Harper. Pp. XIX+324. (London and New York. Macmillan and Co.) Price 10*s.* 6*d.*

The following publications have been issued by this Department since the last issue :—

Review of Agricultural Operations in India, 1928-29. Price Rs. 3-2 or 5*s.* 6*d.*

Catalogue of Indian Insects.

Aluoitidae (Pterophoridae), by T. Bainbrigge Fletcher. (Part 20). Price, Re. 1-6-0.

Lycidae, by R, Kleine (Part 21). Price, Re. 1-2-0.

Phaloniadae and Chlidanotidae, by T. Bainbrigge Fletcher. (Part 22). Price, As. 6.

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Scientific Reports of the Agricultural Research Institute, Pusa (including the Reports of the Imperial Dairy Expert, the Physiological Chemist, Government Sugarcane Expert, and Secretary, Sugar Bureau), for the year 1927-28. Price, Rs. 2-6 or 4*s*. 3*d*.

Scientific Reports of the Agricultural Research Institute, Pusa (including the Reports of the Imperial Dairy Expert, Physiological Chemist, Government Sugarcane Expert, and Secretary, Sugar Bureau), for the year 1928-29. Price, Rs. 2-8 or 4*s*. 6*d*., for the year 1929-30. Rs. 3-8 or 6*s*.

Review of Agricultural Operations in India, 1926-27. Price, Rs. 2 or 3*s*. 6*d*.

Review of Agricultural Operations in India, 1927-28. Price, Rs. 2-6 or 4*s*. 3*d*.

Review of Agricultural Operations in India, 1928-29. Price, Rs. 3-2 or 5*s*. 6*d*.

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Botanical Series.

Vol. XVI, No. IV. Further Studies of Indian Grasses and Grasslands, by W. BURNS, D.SC (Edn.), L. B. KULKARNI, M.Ag. (Bom.), and S. R. GODBOLE, B.SC (Bom.). Price, Re. 1-4 or 2*s*. 3*d*.

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Vol. XVI, No. VI. Studies in Indian Pulses: I. Lentil (*Ervum lens* Linn.), by F. J. F. SHAW, D.SC., A.R.C.S., F.L.S., and RAKHAL DAS BOSE, B.SC. Price, Re. 1-10 or 2*s*. 6*d*.

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Vol. XVII, No. III. Cotton Wilt, by JEHANGIR FARDUNJI DASTUR, M.SC. Price Re. 1-4 or 2*s*. 3*d*.

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